AstroSim2017
From parallel architectures
To parallelized applications

Travels, tries, traces, traps, tricks, trends and trolls...

Event log of a native physicist inside the world of parallelism...

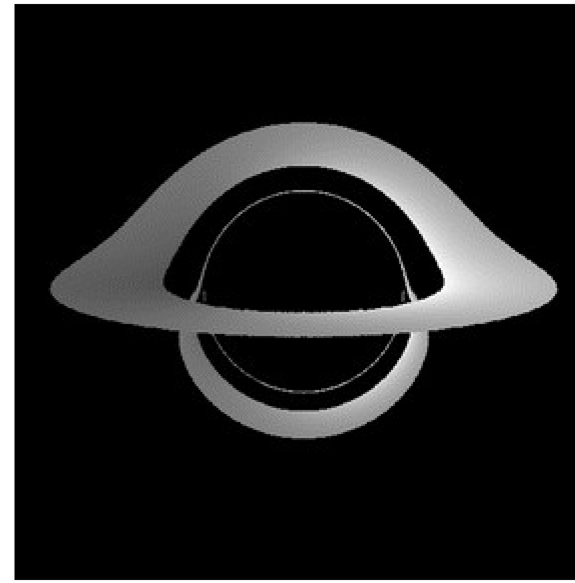
How the heat frontier led disruptive technologies…

Emmanuel Quémener

Warnings about your lecturer...

- I'm french
  - And all TV series are translated in France (so, no improving english via TV :-( )
- I'm a « production » of french university 25 years ago
  - And english learning & speaking was not clearly a priority
- I'm not graduate in computers
  - But I use computers since 1984 and Debian Linux for 20 years
- I'm a physicist
  - And I worked on gravitational lenses and their application to Lambda in 1994
- I'm research engineer
  - But I improve my knowledge on all IT domains since 20 years…
- The most important thing I learn this 25 years :
  - « If you can not prove that the work is done, it is not worth undertaking it ! »

My (chaotic) adventure in 1 slide From astrophysics to computing



- 1993 : Master 1 in astrphysics (Toulouse)
  - Code simulating of Gravitational Lenses
- 1994 : Master 2 in astrophysics (Paris-Meudon)
  - « Reloaded » of JPLuminet Black Hole image
  - Use of Gravitational Lenses to constrain Cosmological Constant
- 1995-1999 : PhD in optical processing (ENST-Bretagne)
  - Lots of Modelisation, Simulations of optical benchs
  - System Administation of my laboratory, Debian user since june 1996
- 1999-2005 : System & Network Engineer (ENS-Cachan)
- 2006 : Project engineer on JWST Nirspec (CRAL, Lyon)
- 2007 : Research engineer in LIP (Computing & Parallelism Laboratory, ENS-Lyon)
  - Gridification of applications as RAMSES in LEGO project
- 2007-2009 : IT supervisor of ENS-Lyon
- 2009- : Research Engineer & IT Test pilot (Blaise Pascal Center, ENS-Lyon)

Centre Blaise Pascal :
Experimental platform with 10 technical facilities

- Multi-nodes : 5 clusters from 4 to 64 nodes, Nodes/Cores : 4/24, 8/64, 8/64, 64/512
- Multi-cores : 10 from 2 to 20 cores,
  - Nodes/Servers : from 8 to 20 cores, Workstations : from 2 to 16 cores
- GPU & Accelerator : 36 different models of GPU (AMD & Nvidia), 1 Intel MIC
  - GPGPU : 8 ; GPU Nvidia : 18 ; GPU AMD/ATI : 10 types ; Xeon Phi 7120P
- Integration : 14 virtual machines : Debian from Lenny to Sid in 32 & 64 bits, ...
- Exotic hardware : 3 machines ARMv7 under Debian Jessie or Ubuntu
- 3D facilities : 2 workstations, 2 video projectors, 20 monitors, 4 glasses
- Remote desktop facilities : more than 25 hosts with x2go/VirtualGL
- COMOD with SIDUS : « Compute On My Own Device » for laboratories users
  - SIDUS is « Single Instance Distributing Universal System »
- Galaxy project demonstrator for data intensive biomedical research

Warnings about this course What it will **not** be ...

- A introduction to general parallel computing
  - https://computing.llnl.gov/tutorials/parallel_comp/
- An introduction to parallel langages
  - MPI : https://computing.llnl.gov/tutorials/mpi/
  - Posix Threads : https://computing.llnl.gov/tutorials/pthreads/
  - OpenMP : https://computing.llnl.gov/tutorials/openMP/
  - **That's where I learn alone how to…**
- And I'd like to provide you how I would like to learn it.

Parallelism in 7 questions
5 Ws & 2 Hs

- Analytical Method : answer 7 questions
- Why ? What ? When ? Where ? Who ?
- How much ? How ?
- In french, CQQCOQP !
- Interesting approach not to forget :
- Problem : intrication between questions
- Advantage : really separate ambiguities
- Try to answer without to many overlappings !

Why parallelism : //ism is a way... Where we go ? Where we are ?

- Where we are : we all oftently use codes
- Where we go : we want more « performance »
- How to go : parallelism is one way, but why ?
- Before « falling through the rabbit hole » of parallelism :
  - What are the practices on codes ?
  - How to define a performance of a code ?
  - What selected criterium of performance to choose ?
  - How to reach the selected performance ?

Codes & Performance : What definitions to choose...

- Etymology (Etymonline)
  - Code : from latin codex « book, book of laws »
    - « systematic compilation of laws » (1236)
    - « system of telegraphic communication » (1866)
  - Performance :
    - « accomplishment » (of something)
    - meaning « a thing performed » is from 1590s
    - « set of optimal capabilities for a system » (1929)
- And we will choose
  - Code : both :-)
  - Performance : three :-)

If computing was cooking…
Code : only the recipie...

Code ~	Recipie
Computer ~	Kitchen
Input Data ~	Ingredients
Output Data ~	Meal Dish
Process ~	Cooking process
Control Unit ~	Cooker
ALU ~	Utensil
Me ~	Client
Batch Request ~	Order

Some definitions and letters...

- ALU : Arithmetic & Logic Unit
- CPU : Central Processing Unit
- Flops : Floating Point Operations Per Second
- (GP)GPU : (General Purpose) Graphical Processing Unit
- MPI : Message Passing Interface (communication between nodes)
- RAM : Random Access Memory
- SMP : Shared Memory Processors
- TDP : Thermal Design Power
- And several new ones :
  - **PR** : Parallel Rate (NP in MPI, Threads in OpenMP, Blocks, WorkItems in GPU)
  - **Itops** : Iterative Operations Per Second
  - **EPU** : Equivalent Processing Unit (optimal parallel rate deduced)

What’s this ?
Code, protocol of experimentation

- In cuisine :
  - We have all the ingredients, we want to make a dish !
- In scientific ways :
  - Simulation : « On Its Theory (Discrete ?) Service »
  - Processing : for « demanding » experimenters
  - Vizualisation : to see to perceive things (and share)
- Each launch is an experience (and unique one)...
  - Recipies : « codes » becaming « processus »
  - Utensils : librairies, OS, hardware, networks, ...
  - Ingredients : modelisation, data, …
  - Execution : and the experience cannot be restricted to Results

Families of Codes

- What distingish the different codes I use ?
  - « My code I did of mine and I'm proud of »
  - My supervisor code
    - In fact, the stratification of codes produced by previous generations of students
  - Code «business»
    - « Ikea » model : delivered with assembly instructions (without toolbox)

      « Crozatier » model : (almost) ready to use
- Like in every family, problems occur for inheritance
- Dependencies to :
  - Generic librairies : BLAS, Lapack, FFTw
  - Proprietary librairies : Mathworks, Intel, Nvidia, AMD, …
  - Hardware !

Performance : how ? A question of observables !

Sport performance

- To run a 100-metre ?
- To run a marathon ?
- To make shot put ?
- To complete an heptathlon ?

Performance : how ? A question of objectives !

- To put all luggages & family inside the car
- To draw the attention of females outside the night clubs
- To get from point A to point B in a town with traffic jam
- To climb to Pikes Peak




Performance : Conditioned by objectives

- Speed : elapsed time (only?)
- Work : immobilization of resources
- Efficiency : best use of available resources
- Scalability : incremental progress when more resources are dedicated
- Portability : diffusion to other IT infrastructure
- Maintainability : time spent to maintain the system operational
- General approach :
  - Define un criterium
  - Research extreme values (maximum or minimum) for a pertinent test suite

Speed as Performance Criterion « Speed, I'm Speed... »

- All time, but not only « Elapsed time »
- To use code : the 3 costs
  - Entry cost : to learn software, to integrate in infrastructure, …
  - Operational cost : to maintain, to operate
  - Exit cost : substitution by an equivalent code, an equivalent technology (Cell...)
- Optimization (and its problem) : DD/DE > 1 is pertinent ?
  - DE : Total elapsed time for my code
  - DD : time spent to minimize this total elapsed time
- To estimate the value :
  - System tools, metrology tools in langages, codes, ...
  - « Et après moi ? Le déluge ? » : what future for the code ?

Work as Performance Criterion

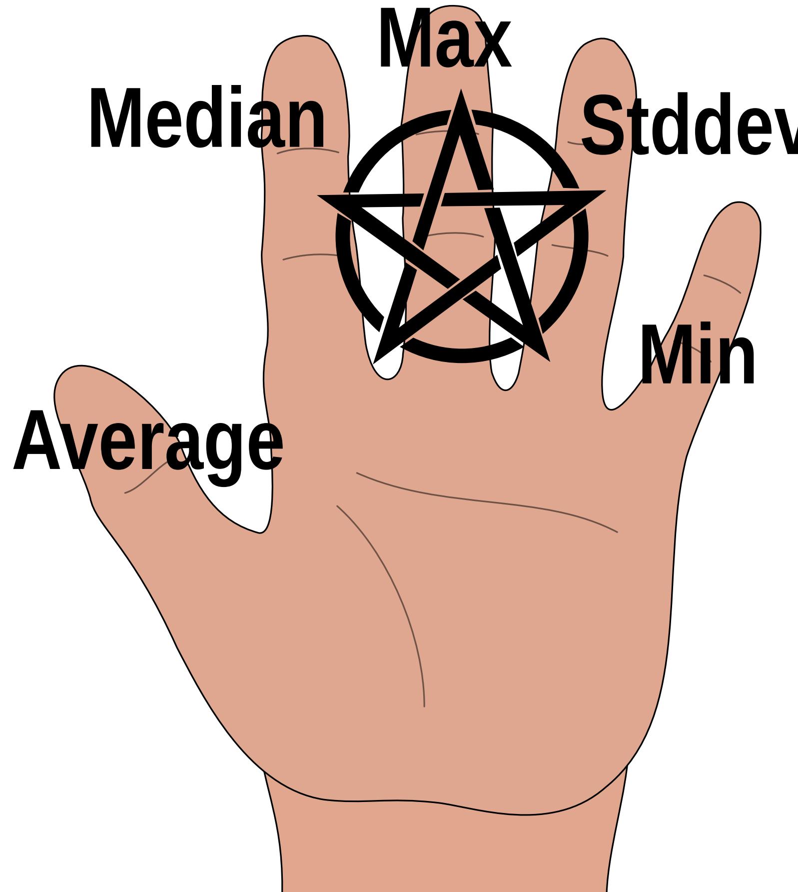
- Work : « Time is money »
  - Ressources : CPU, RAM, GPU, storage, network, ...
  - In fact, a Matriochka :
    - CPU : several cores, CU, ALU, piles, ...
    - RAM/SRAM : 4 levels
    - Storages : local, slow & shared (NFS), fast & shared (GlusterFS, Lustre, ...)
    - Networks : slow (Gigabit), fast & low latency (InfiniBand)
- Job : reservation (& immobilization) of resources
  - Classical : Nodes * Elapsed time
- For a code, « system fingerprint »
  - Profiling tools, System tools

Scalability as Criterion

- Scaling :
  - In the tasks to be done : Elapsed time ? f(Elapsed Time)
  - In required resources : g(System Resources)
- Reefs to avoid :
  - Scaling effects (in fact, threshold effects are even worse)
  - Needing conductor ? From a Quatuor symphony orchestra…
  - Although you execute, the available resources are limited…
    - You think I'm joking :-/ ?
- **Parallelization becomes unescapable, but why ?**

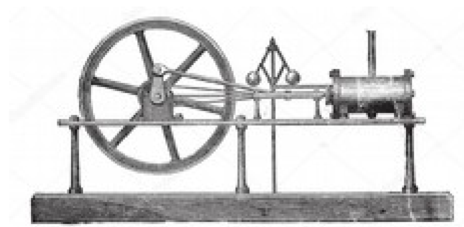
Measure of Performance & Scalability Pen(s)tacle of statistics:

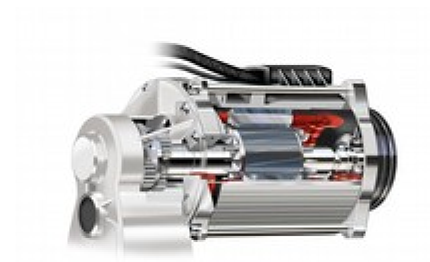
- Why improving statistics ?
  - Because you practice sciences !
- The pentacle of statistics
  - **Average** : the first we think, but bad one
    - Initialisation process, random tasks
  - **Median** : the one to prefer
  - **Max** : The slowest is the most awaited
  - **Stddev** : indicator of variability
  - **Min** : the best case is to know
- **Variability** : ratio Stddev/Median



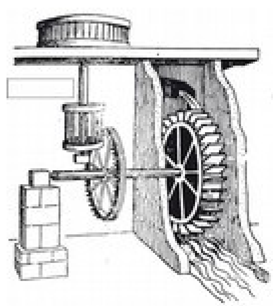
Energy : Engines & Humanity APU from beasts to silicone…

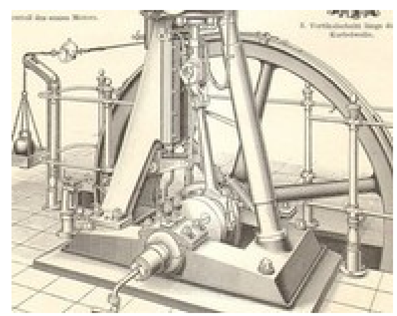
APU : Auxiliary Power Unit

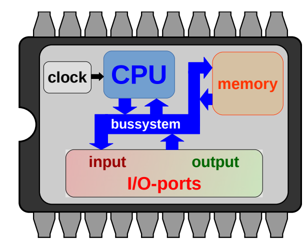




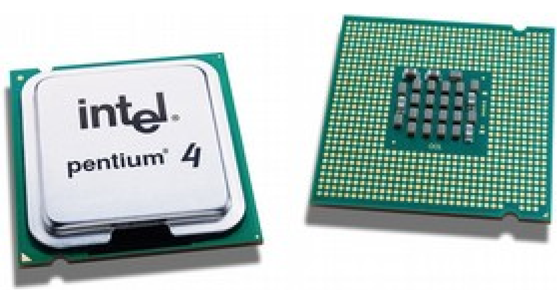
From ancient time to the present day...

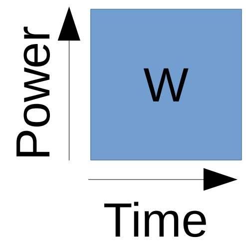






Work on Computing Resources from a Physicist Point of View

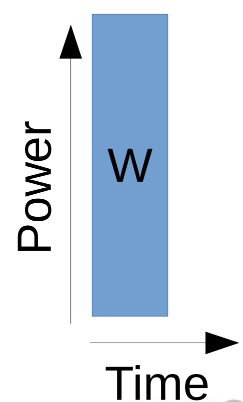




Mechanics

$$W = \int_{x_1}^{x_2} F\,dx = \int_{t_1}^{t_2} P\,dt$$

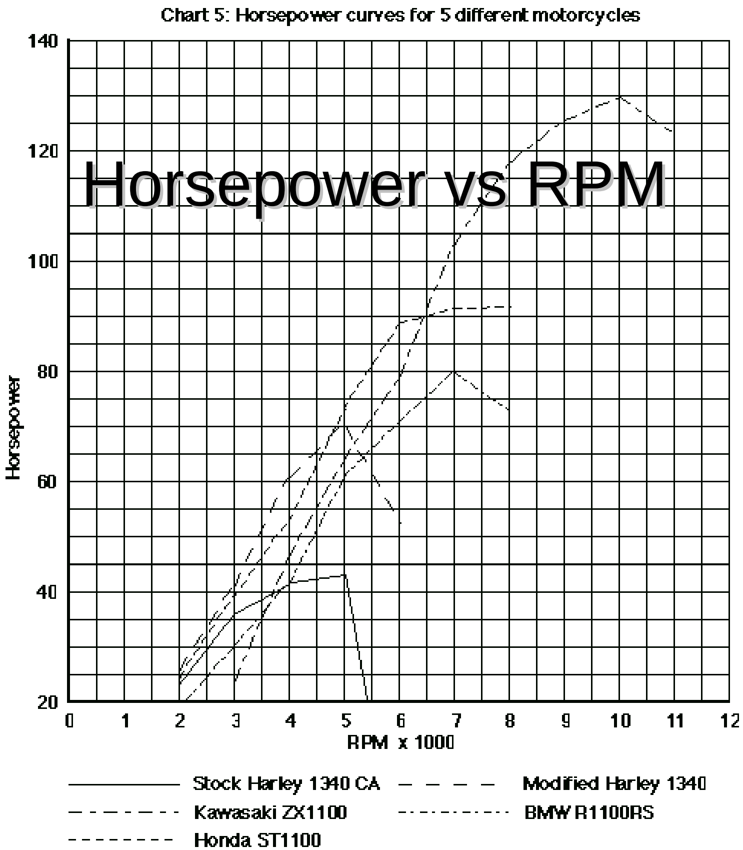
Thermodynamics

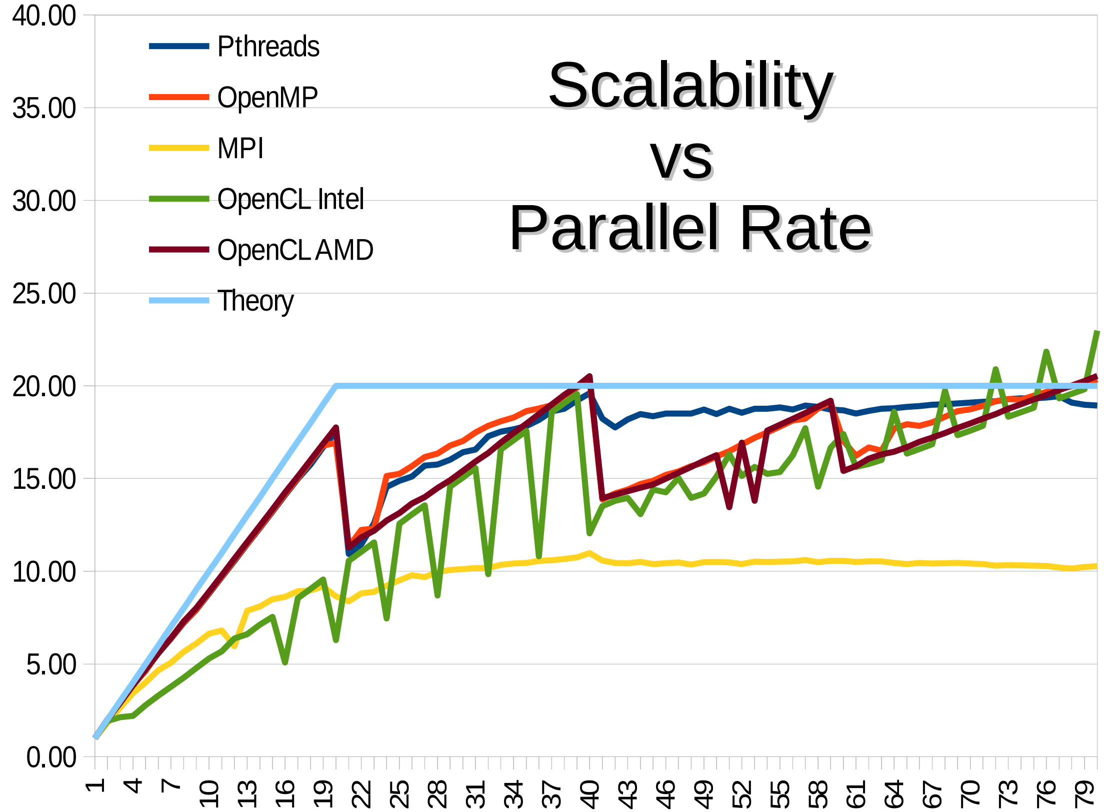


Power equals product :

- Frequency
- Number of Workers
- Power of 1 Worker

Work on Computing Resources
An Engine as the source of Power

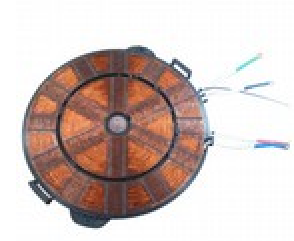




- What "behaviors" for these engines at "load-bearing"?
- The "engine", a system entangling hardware, OS and software

Why Parallelism (is inevitable) ? And its constraint is TDP

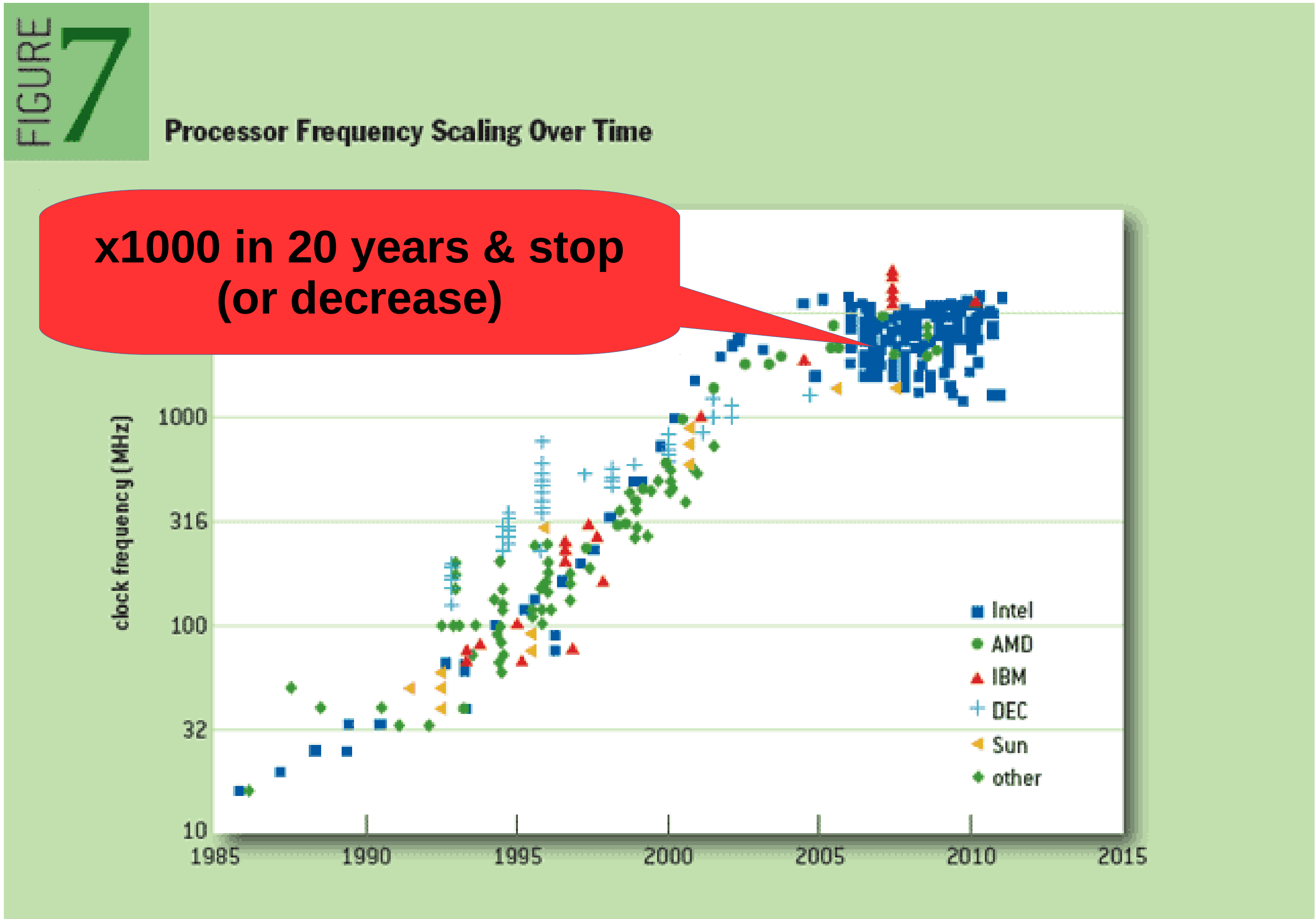
- Rise and Fall of Frequency
  - Between 1989 and 1999 : from 4 MHz to 400 MHz   x100 in 10 years
  - Between 1999 and 2004 : from 400 MHz to 3 GHz   x~10 in 5 years
  - Between 2004 and 2009 : from 3 GHz to 2 GHz
- Thermal Design Power : limited power of socket no to overshoot...
- TDP = $\frac{1}{2} C V^2 f$
  - C = Capacitance, f = frequency, V = voltage
- TDP for a processor : 150 W (on 4 cm^2)
  - Density of heat of an Induction Hob
- TDP becomes the blocking factor of a processor



Capacitance = $Schrink^2$. Nb Transistors . Mylq Constant (~ 0.015)

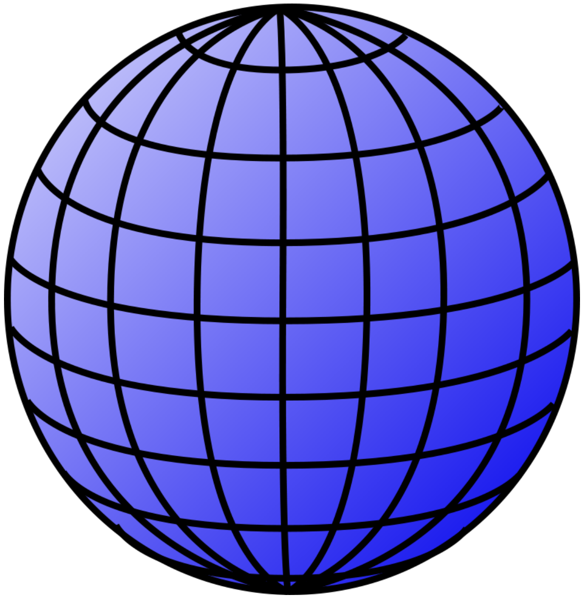
Viable solution: increase number of processing units (PU)

Why Parallelism ?
When Clock Speed ~ Velocity...



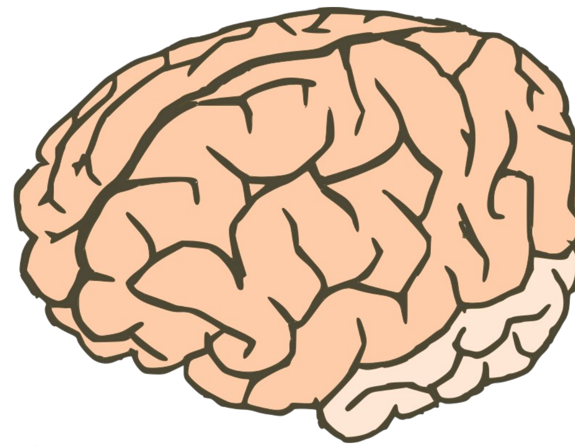
What is Parallelism ? Let's « Return to the Source »

- Etymology (etymonline.com) : beside one another
  - From para- « beside »
  - From allelois « each other », from allos « other »
- Parallelism : tasks to achieve, limited ressources...
  - Execute independant tasks in parallel
- Execute one task in parallel on all resources
  - Sparse communications : Coarse grain
  - Heavy communications : Fine grain
- Paradox of parallelism, meridian !



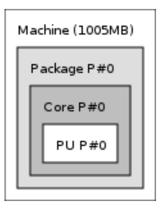
Where is Parallelism ?

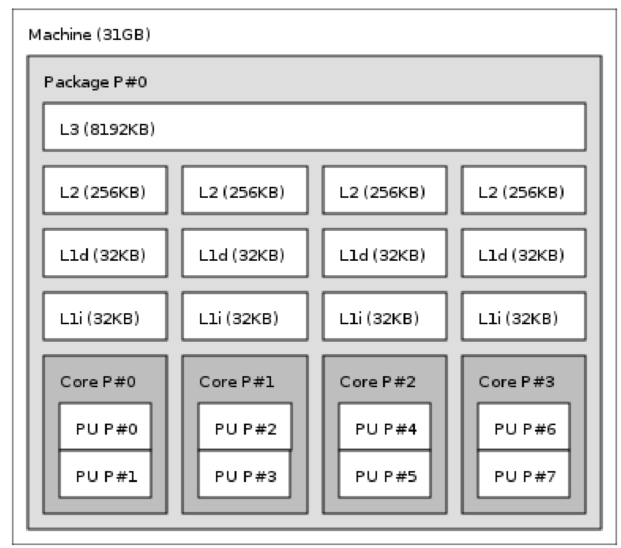
- Where is the best computer ?
  - Between your ears !
  - 20 to 200 billions neurons
  - 125 to 220 trillions synapses
  - Computational capacity (IBM) : 36 Pflops, 3.2 Pbytes



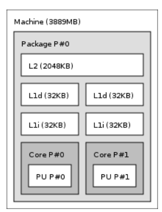
- The best GPGPU processing card :
  - 3584 ALUs
  - 16 GB and 720 GB/s of Bandwidth
  - Process capability : 9.3 Tflops
  - In fact, getting 4 Tflops (FP64), it's amazing !

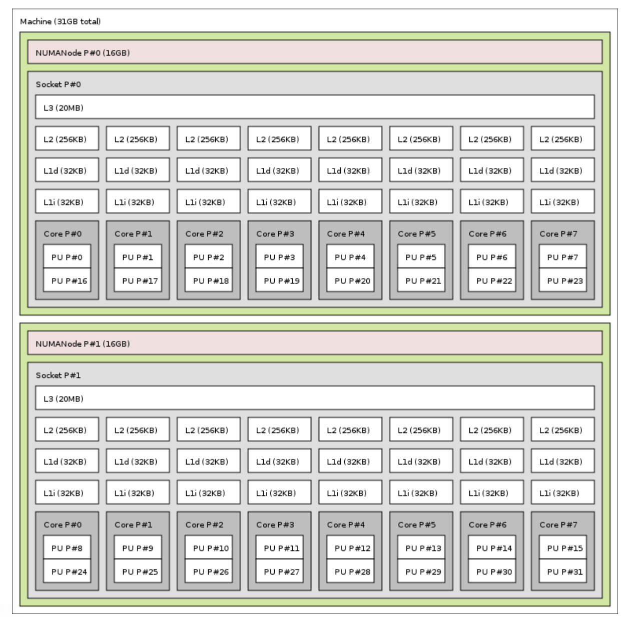
Evolution of machines…
From 2004 to 2013, on laptops !



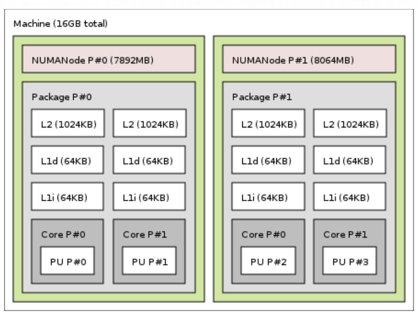


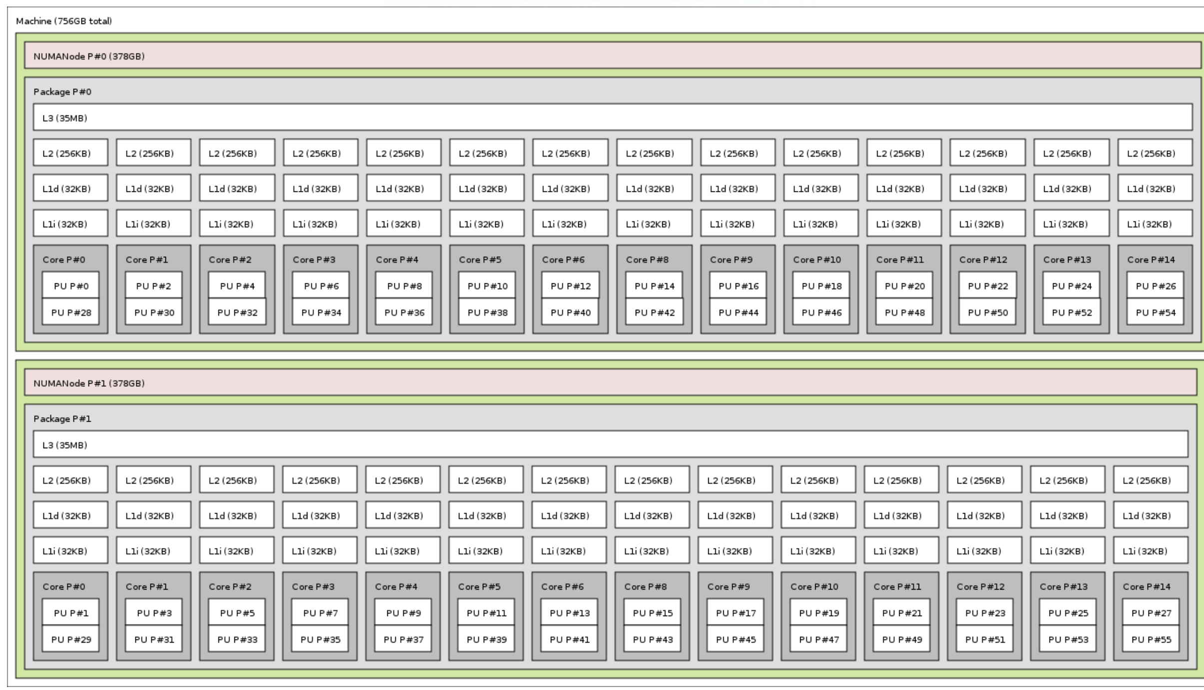
Evolution of machines…
From 2007 to 2016, on workstations



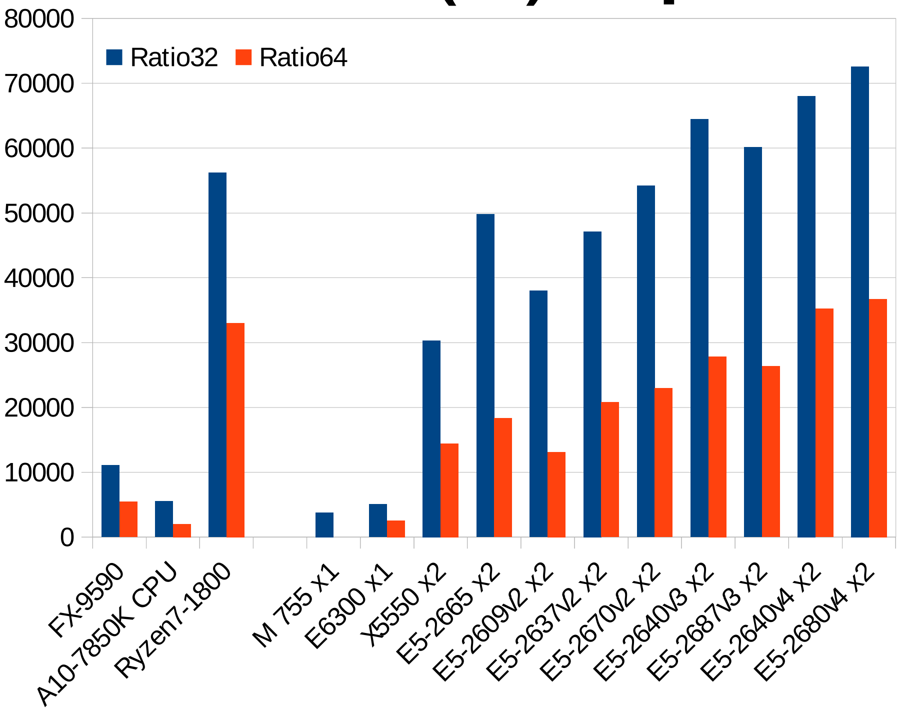


Evolution of machines…
From 2007 to 2016, on servers...

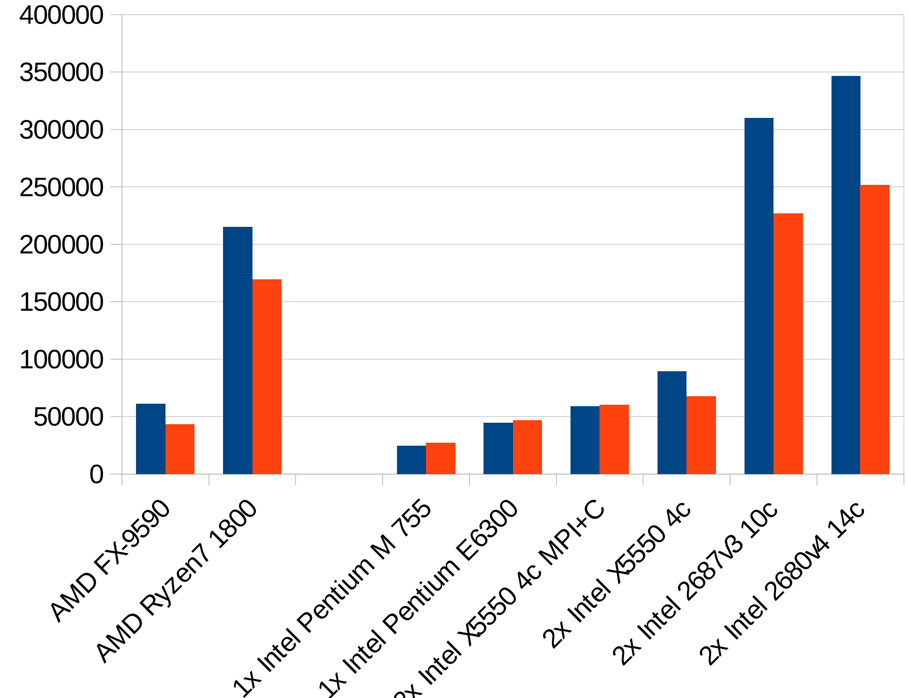




Renormalization of Performances for CPU(s) : per core, per MHz



Nbody Test Code



Pi Monte Carlo Test Code

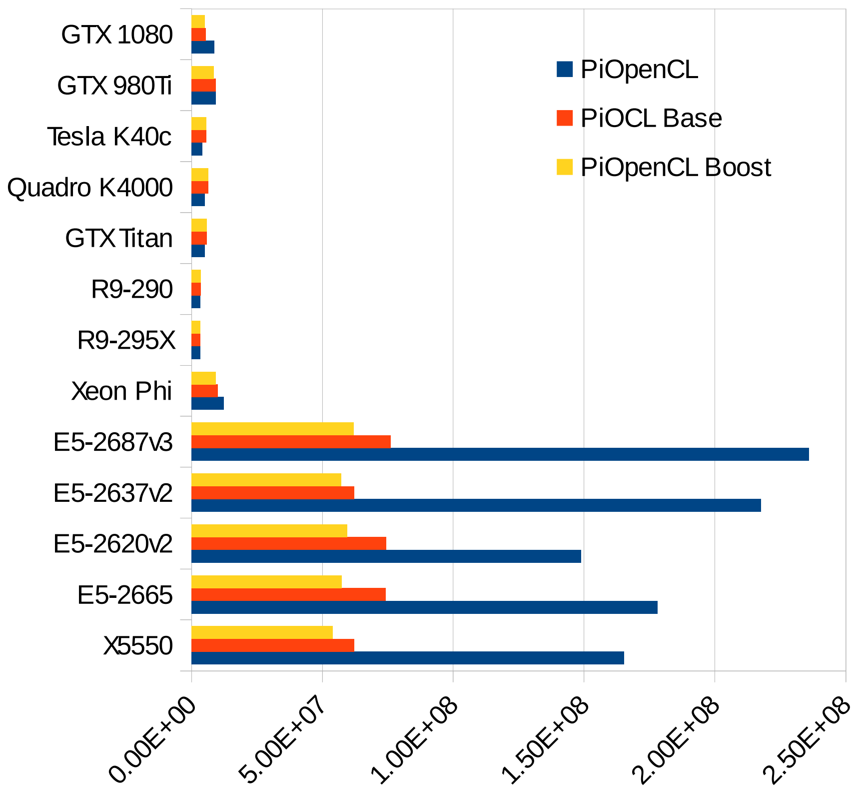
Yes, it improves with time, fortunately, x10 !
(but ONLY for vectorized codes...)

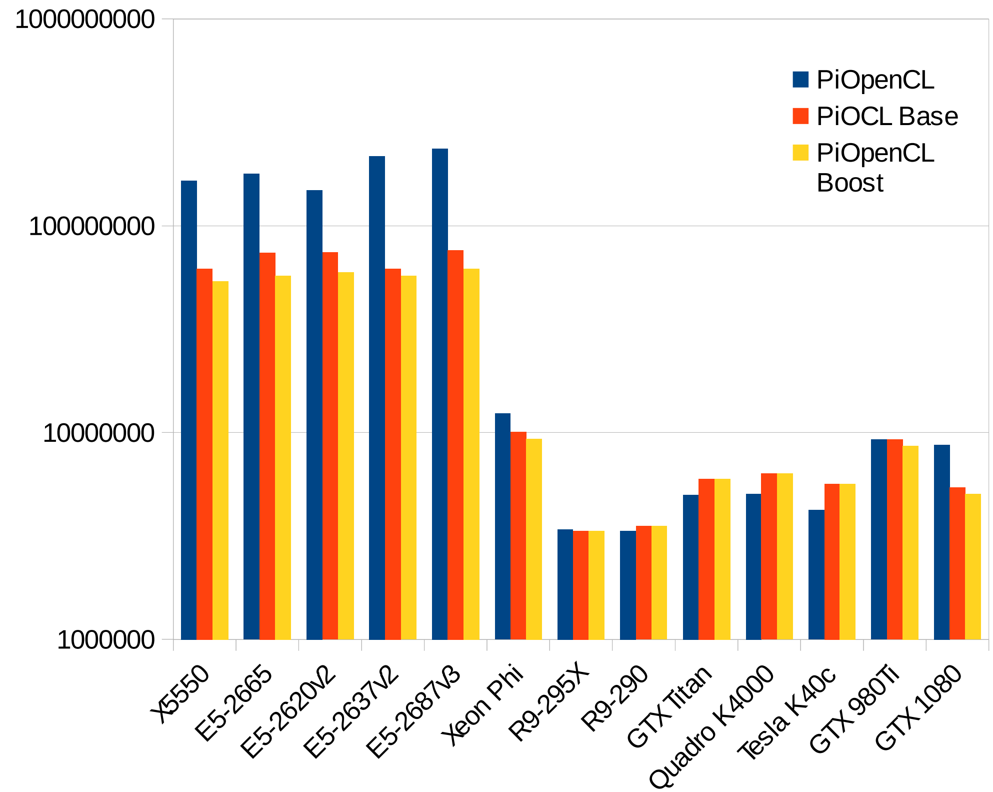
How much is Parallelism ? Time, Silicone, Complexity...

- The 3-Time costs :
  - Entry cost, Operating cost , Exit cost
  - Execution time compared to adaptation time
- Silicone : technologies have different prices
  - SMP (Shared Memory Processors) are expensive & limited
  - MPP (Massively Parallel Processing) need very specific networks
  - Clusters are easely extensible
- Complexity : corollary of large amount of gates
  - A GPU « core » (QPU) is simpler than a CPU core
  - A GPU « core » (QPU) is about 50 times slower than CPU core

With sequential (old) programs, CPU beats GPU! Old ~ New CPU !

- From 20 to 50x slower!



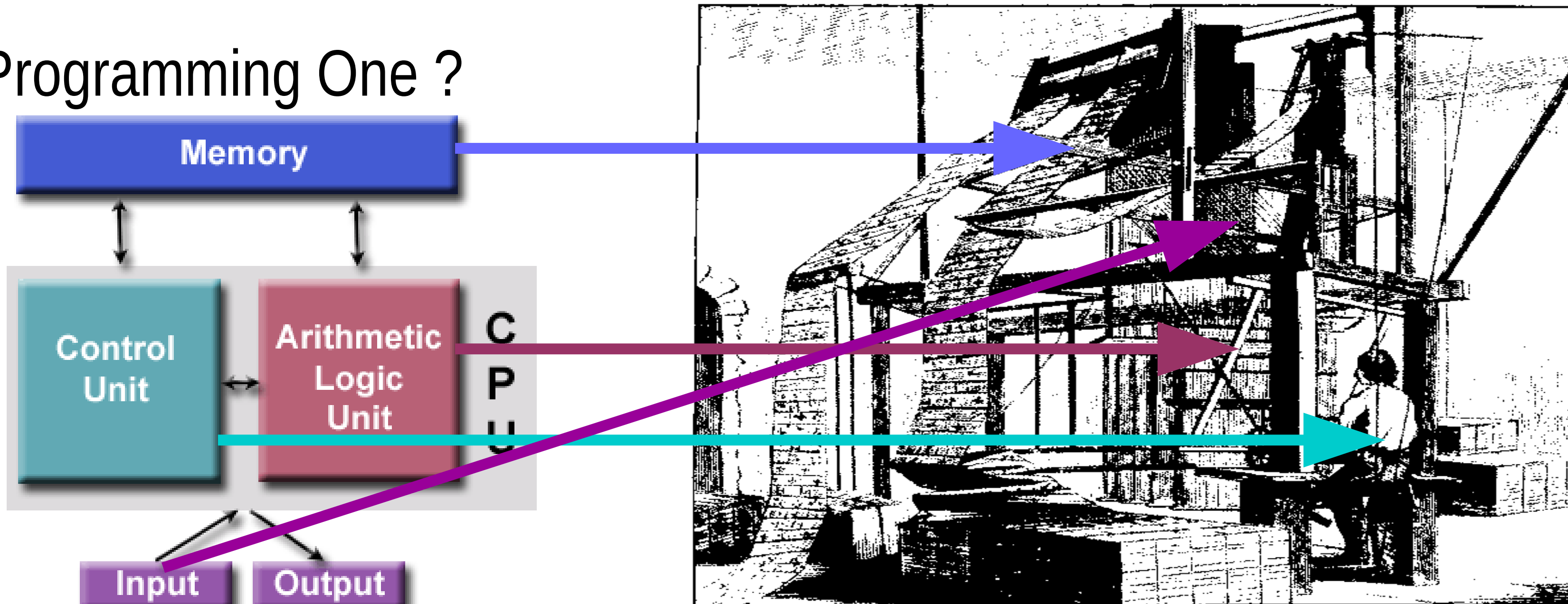


- 1.5 order of magnitude ...

When appeared Parallelism ?
With « computing » machines !

Which is the first ?

- Analogical One ?
- Numerical One ?
- Programming One ?



How to « think » : Parallelism : « Grain... The problem is Grain. »

- 1 Input / 1 Process ? Optimize process !
- 1 Input / Y Process ? Optimize each process !
- X Inputs / 1 Process ? Optimize distribution !
- X Inputs / Y Process ? Optimize both !

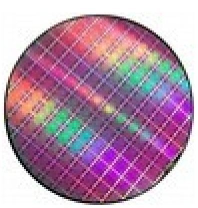
Grain is defined by communication rate !

- Fine grain : heavy communications (>> 1/second)
- Coase grain : sparse communications (< 1/second)
- Embarrassing parallelism : independant tasks

How to « think » ParallelisM : Flynn Taxonomy

- SISD : Simple Instruction Simple Data
- SIMD : Simple Instruction Multiple Data
  - Vectorization

- MISD : Multiple Instructions Simple Data
  - Pipelining
- MIMD : Multiple Instructions Multiple Data



Let's have a look

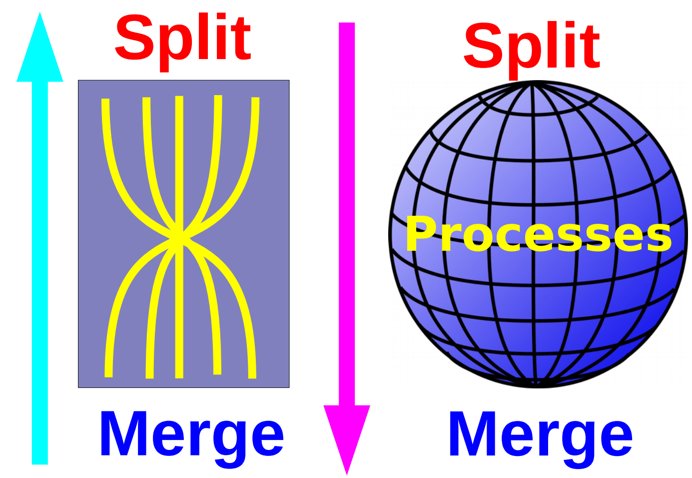
« Behind the Kitchen Door » (In Silicon) ?

How to Parallel Programming ? Split/Merge between process(es)

- Pipelining fine grain, a job for silicon :
  - 5 simple instructions @ a time
    - Intruction Fetch
    - Instruction Decode
    - Execute
    - (MEM)
    - Write Back
  - 2 specs of RISC : 1 instruction/cycle, using registers

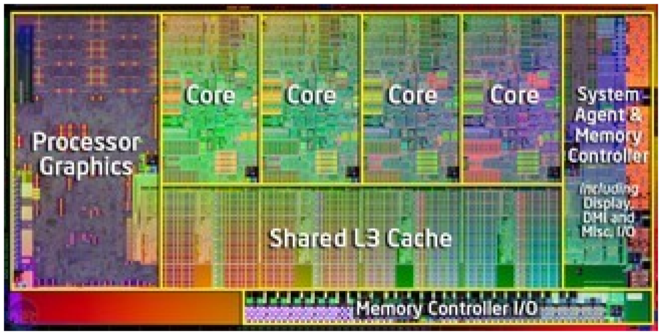
Instr. No.	Pipeline Stage						
1	IF	ID	EX	MEM	WB		
2		IF	ID	EX	MEM	WB	
3			IF	ID	EX	MEM	WB
4				IF	ID	EX	MEM
5					IF	ID	EX
Clock Cycle	1	2	3	4	5	6	7

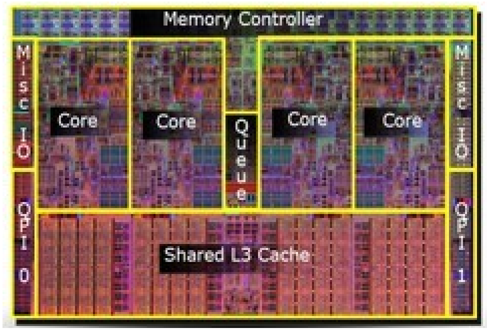
- 2 approaches :
  - Vectorization : Merge/Process/Split
  - Distribution : Split/Process/Merge
- In fact, not parallize but meridianize

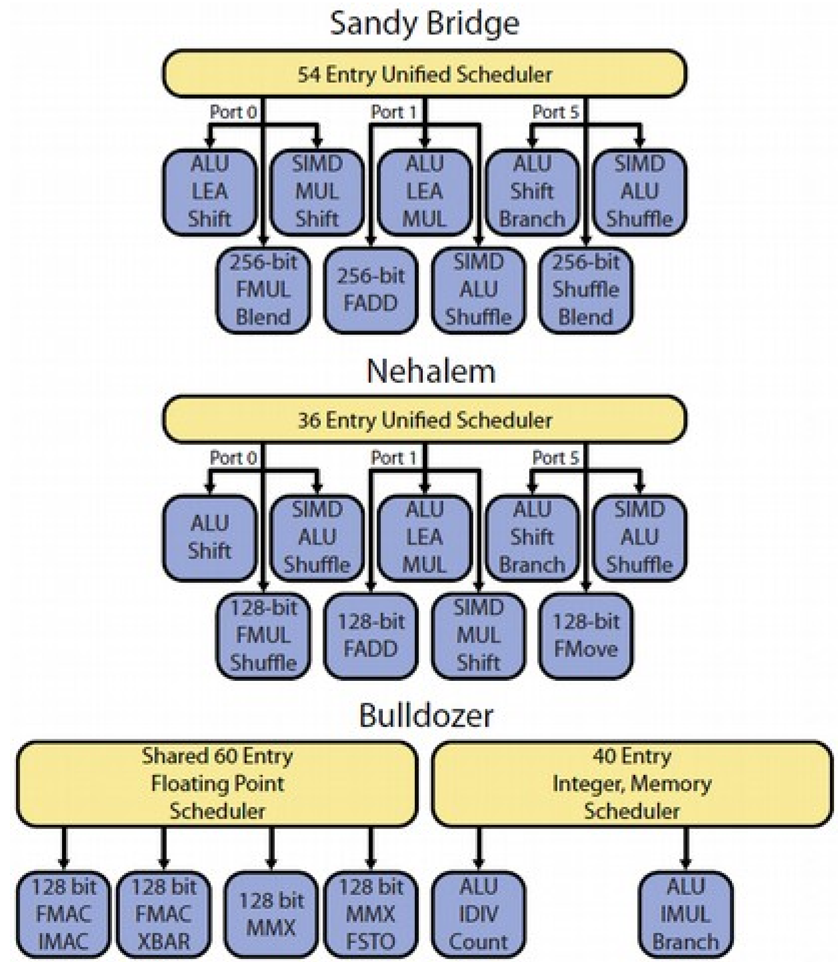


To be (a matriochka) or not to be ? From a processing point of view

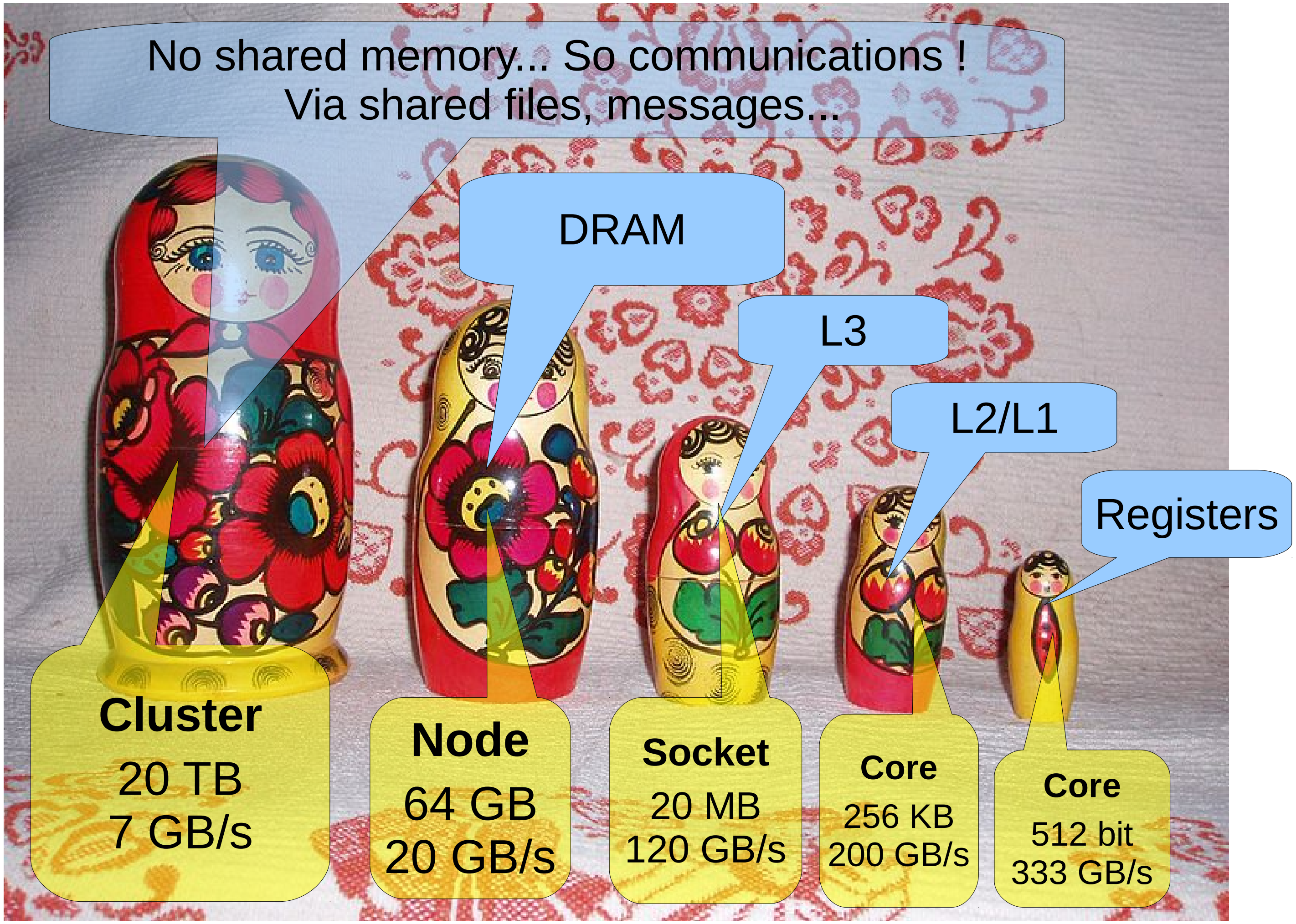
Inside a processor (on a Socket)
4-cores Processors Example







To be (a matriochka) or not to be ? Hierachical Memories !



If computing is cooking…
For Memory...

Code ~ Recipie

Computer ~ Kitchen

Input Data ~ Ingredients

Output Data ~ Meal Dish

Process ~ Cooking process

Control Unit ~ Cooker

ALU ~ Utensil

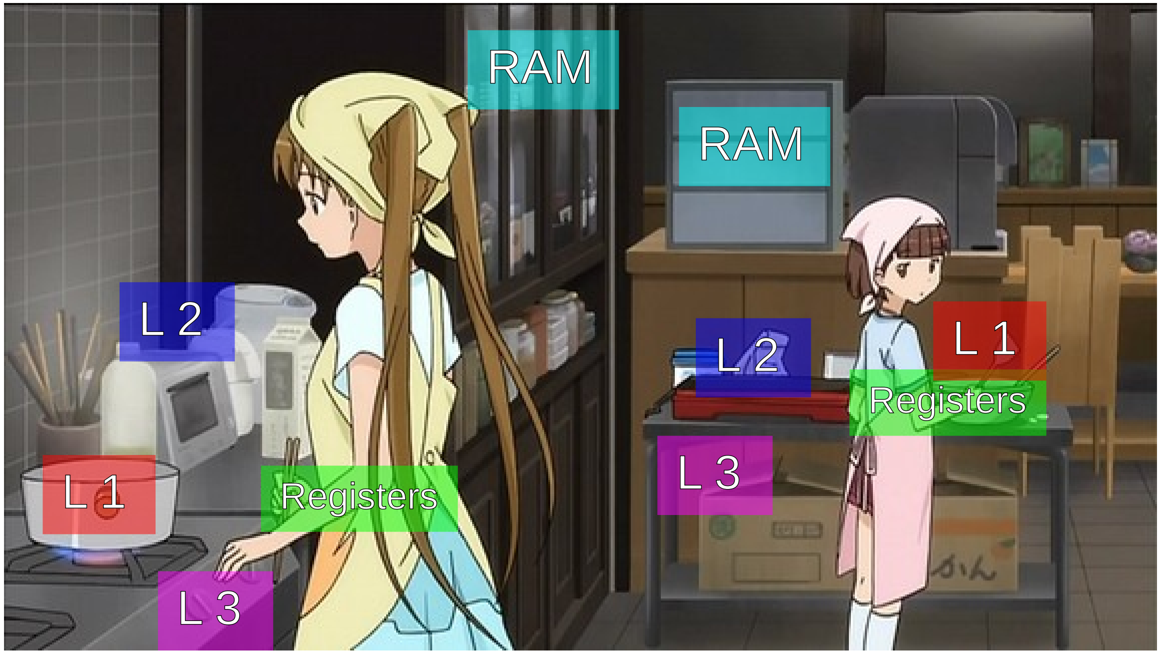
Dynamic RAM ~ Cupboards, tables, ...

L3 Cache ~ All Working planes

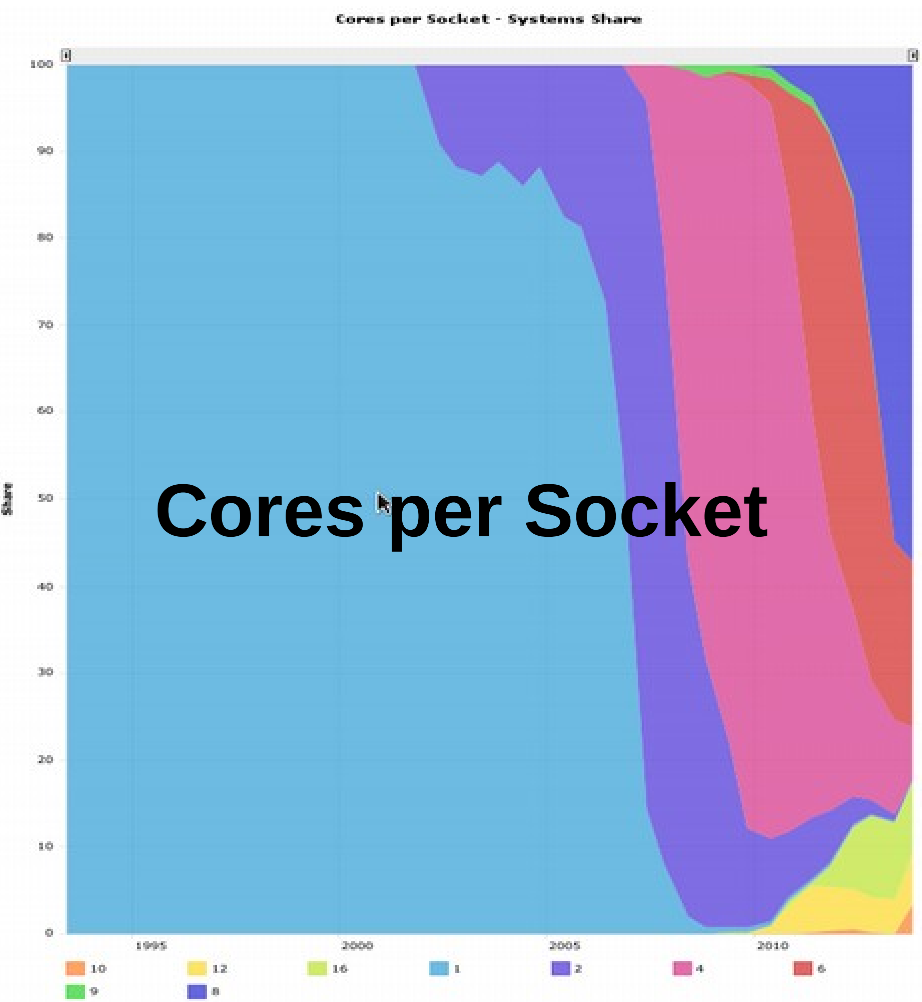
L2 Cache ~ Near Working plane

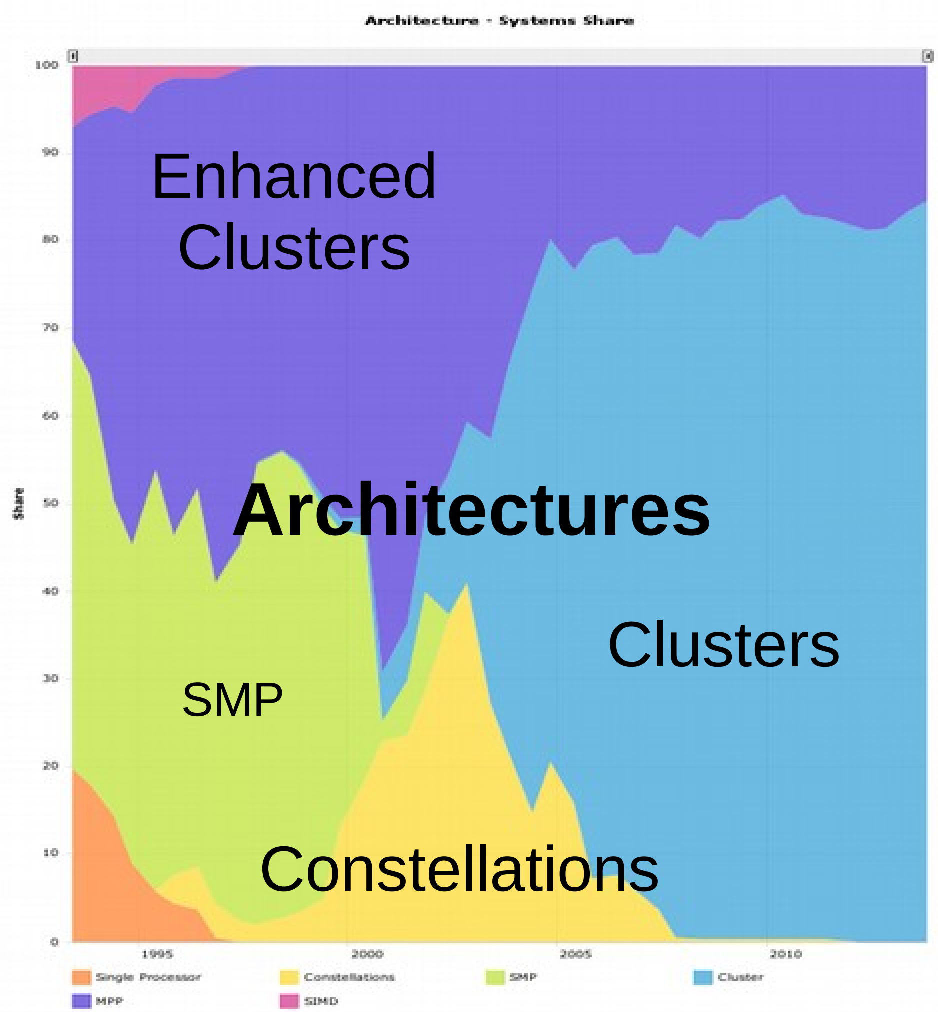
L1 Cache ~ Cutting board, container

Registers ~ Hands of Cooker

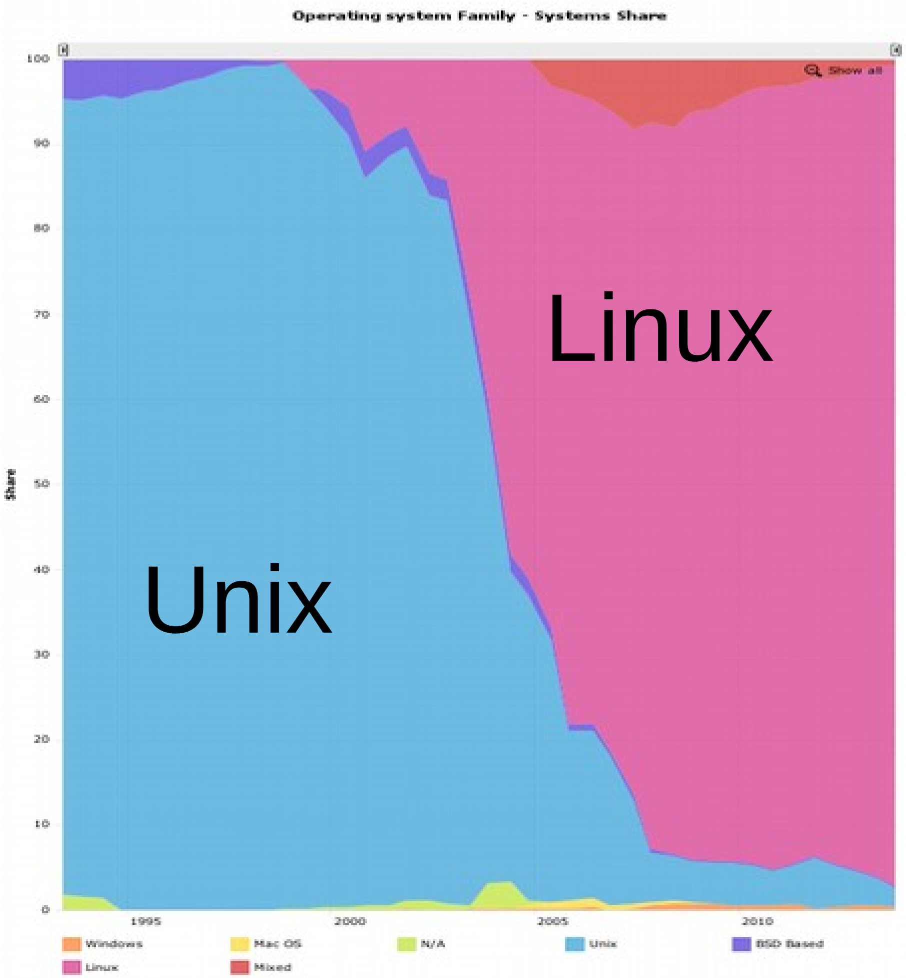


Where you are ? Where you (will) go ? Cores per Socket & Architecture...





Have a quick look on OS
And accelerator stuff !



How much Parallelism ?
From multi-core to myri-ALU

- CPU, 4 in laptop, 16 in workstation, 48 in node
- From GPU to GPGPU :
  - A tiny GPU card : 128 ALU, 512 MB of RAM
  - A huge GPU card : 4096 ALU, 6 GB of RAM
- A huge GPGPU card : 3584 ALU, 16 GB of RAM
- Accelerator Xeon Phi : 61 CPU (Pentium like units)

How to program parallelism ? Different approaches

Parallel Programming Models

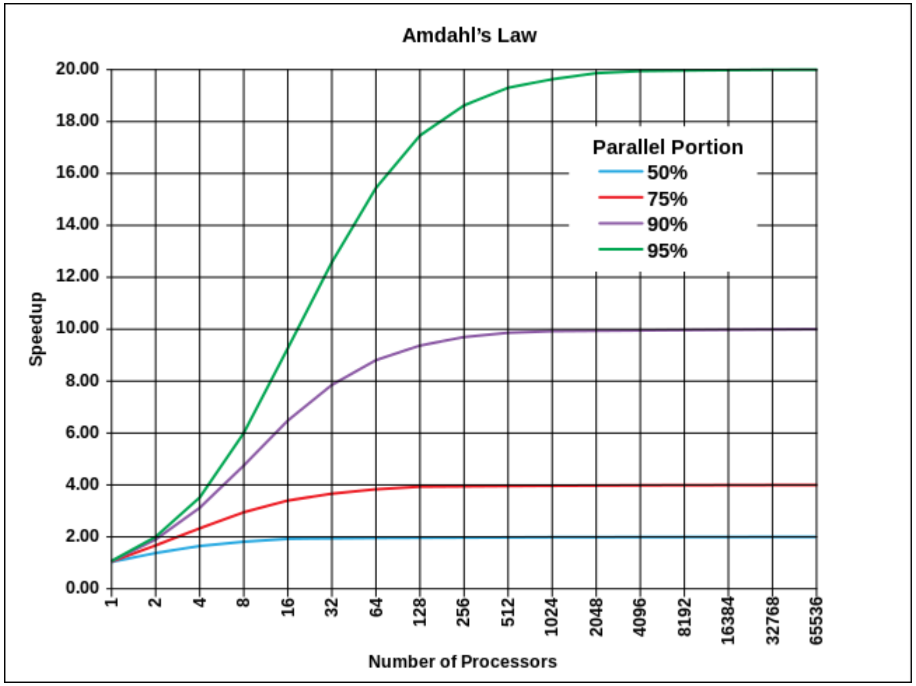
	Cluster	**Node CPU**	Node GPU	Node Nvidia	Accelerator
MPI	Yes	Yes	No	No	Yes*
PVM	Yes	Yes	No	No	Yes*
OpenMP	No	Yes	No	No	Yes*
Pthreads	No	Yes	No	No	Yes*
OpenCL	No	Yes	Yes	Yes	Yes
CUDA	No	No	No	Yes	No
TBB	No	Yes	No	No	Yes*

Parallel Programming Libairies

	Cluster	**Node CPU**	Node GPU	Node Nvidia	Accelerator
BLAS	BLACS MKL	OpenBLAS MKL	clBLAS	CuBLAS	OpenBLAS MKL
LAPACK	Scalapack MKL	Atlas MKL	clMAGMA	MAGMA	MagmaMIC
FFT	FFTw3	FFTw3	clFFT	CuFFT	FFTw3

How to estimate // Efficiency ? Amdahl Law, order (and decay)

- In the process, 2 parts
  - Sequential part, in fraction s
  - Parallel part, in fraction p
  - Elapsed Time : $T_N=T_1(s+p/N)$
  - Speedup : 1/(1-p+p/N)
  - Efficiency : 1/N(1-p+p/N)



- Speed up (& efficiency) :
  - 2 systems : N=500 & N=1000
  - 4 cases : 90 %, 99 %, 99.9 %, 99.99 %

How to estimate Parallel Efficiency ? Amdahl Law, order (and decay)

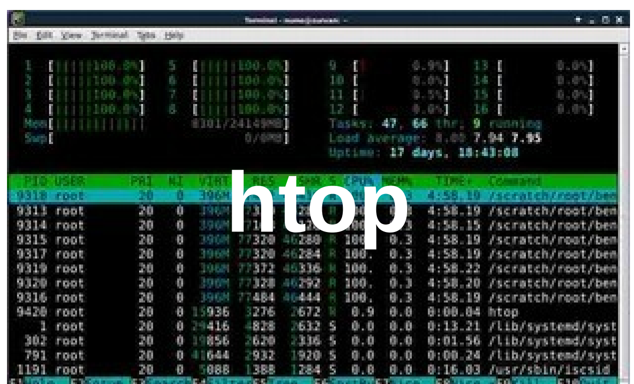
- Speed up (& efficiency) : N=500 & N=1000

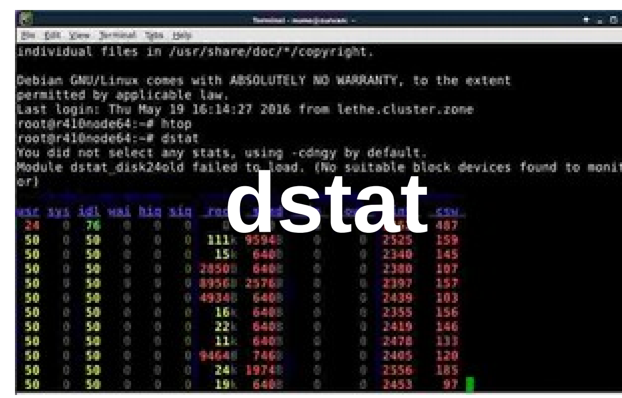
Parallel Rate	N=500		N=1000	
Parallel Part	Speedup	Efficiency	Speedup	Efficiency
90%	9.8	2%	9.9 (+0.1%)	1%
99%	83	17%	91 (+9%)	9%
99.9%	334	66%	500 (+50%)	50%
99.99%	476	95%	909 (+91%)	91%

- Questions :
  - What's about scalability of my code ?
  - Is Amdahl law representative of « real » applications ?

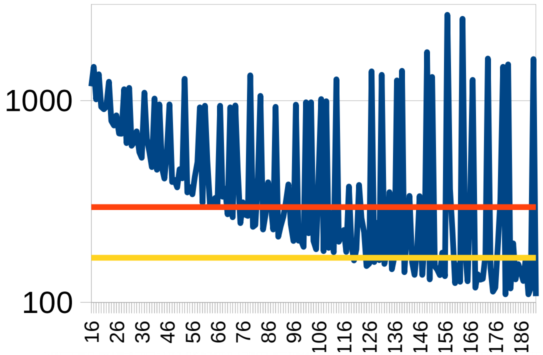
Have you got your driving licencing... In computer sciences ;-) ?

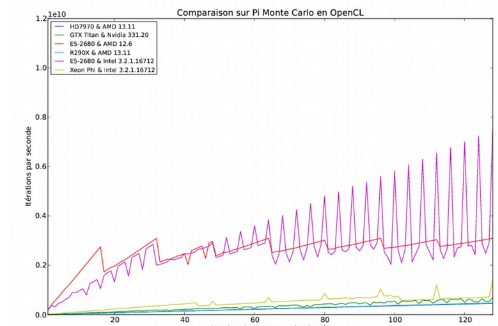
- In an applied mathematics french book :
  - « Physicists are casual in the use of mathematics that mathematicians often equate with carelessness... »
- As a BOFH of IT resources :
  - « Scientists are casual in the use of computing resources that I often equate with my english speaking ! »
- Do you « drive » computing resources ?

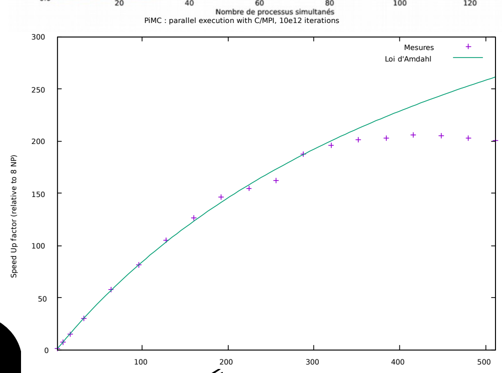


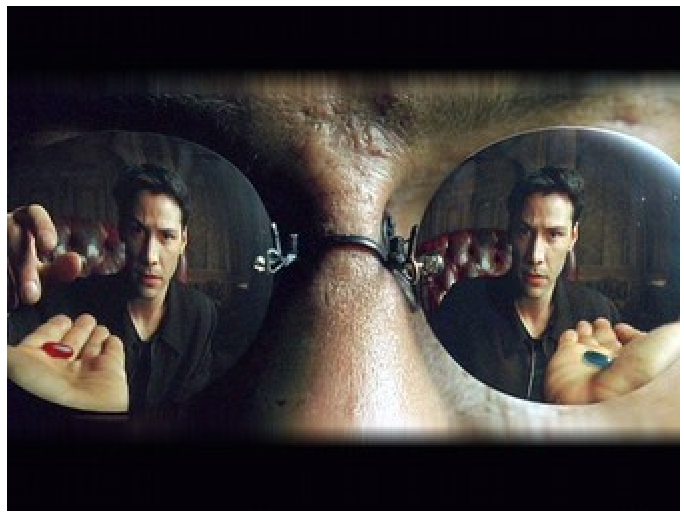


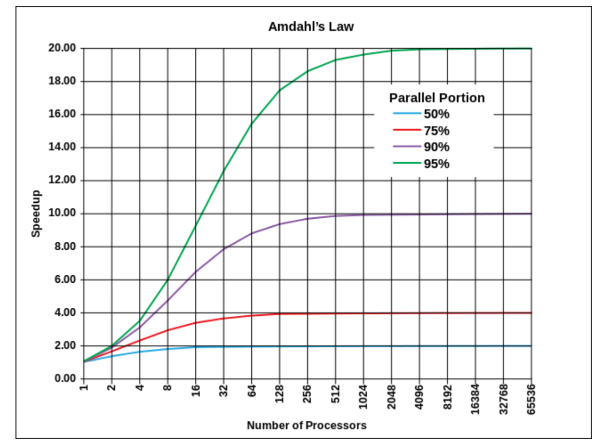
Amdahl law or lie ?
Are you ready to take the Red Pill ?

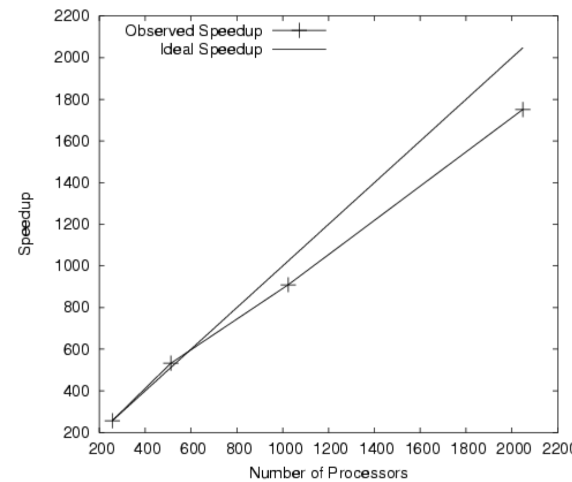




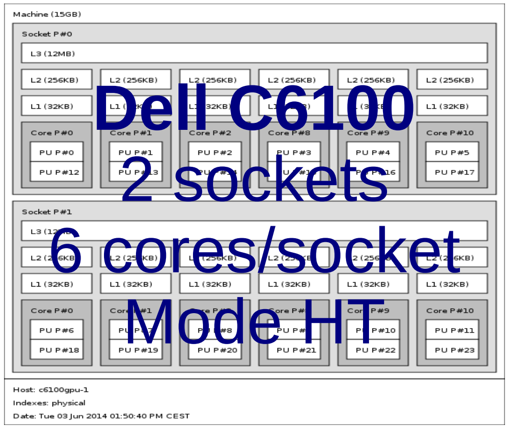


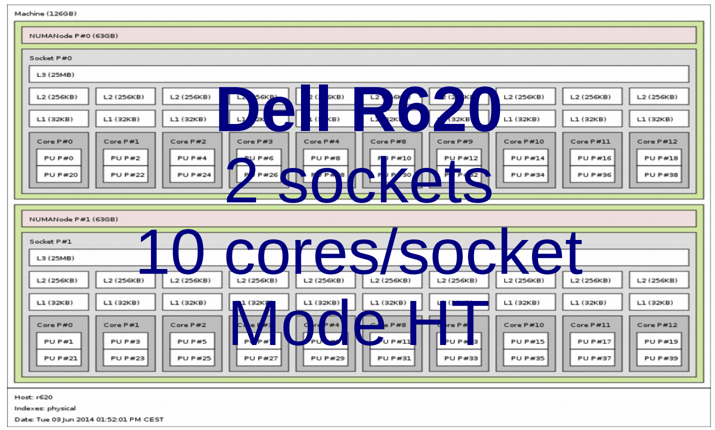


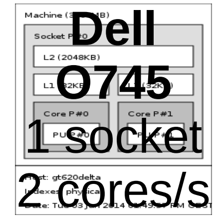


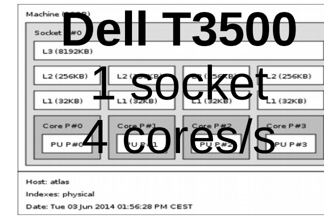


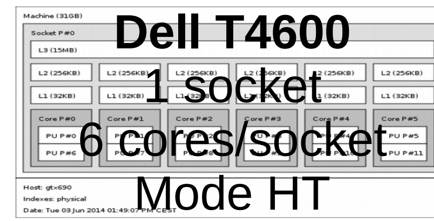
Welcome, Amdahl, to the Real World !
10 machines from 2 to 40 cores...

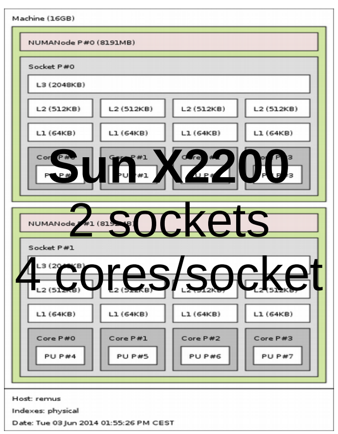


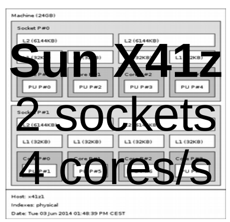




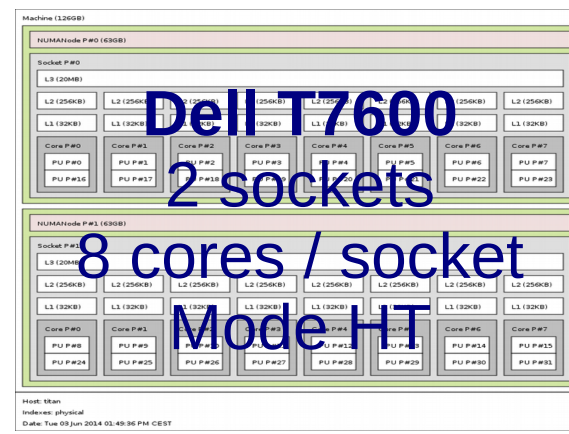


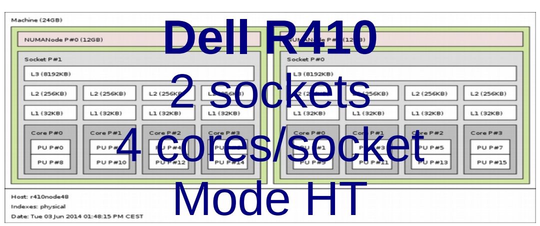


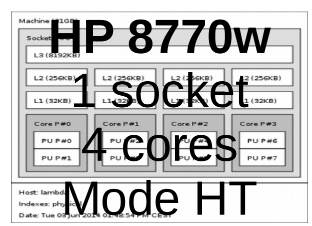




hwloc-ls as command

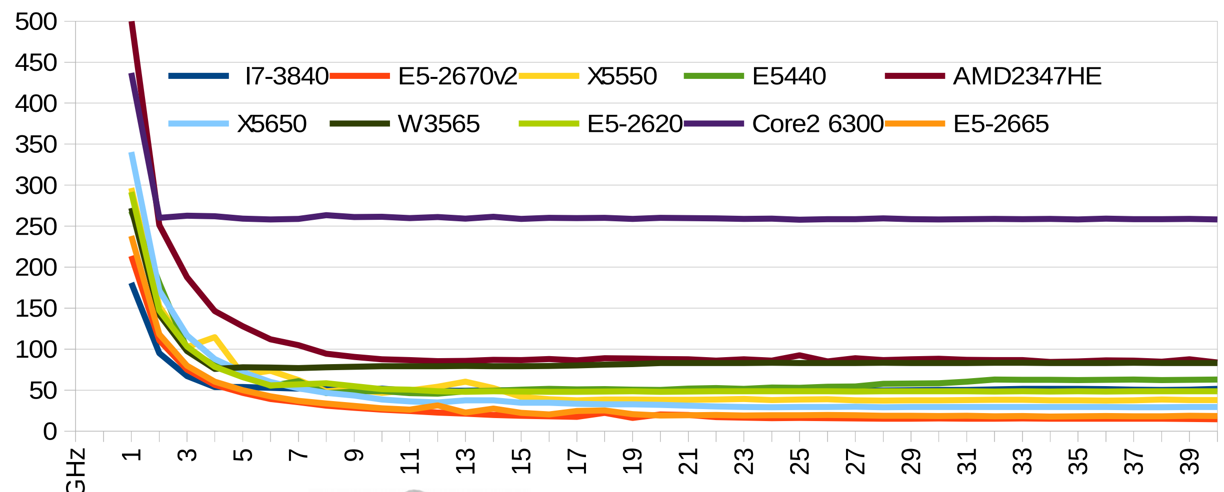






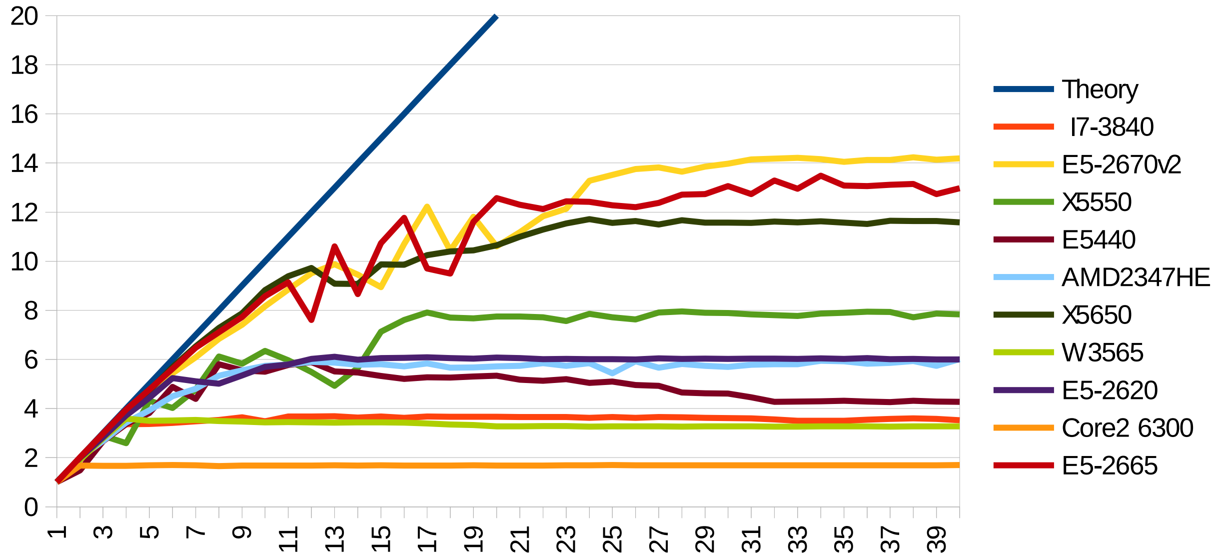
Amdahl Law in the real world
A test bench : 10 CPUs, 1 code

- Inside a node, 2 processors :
- 10 different CPUs, from 2 to 20 cores (40 in HT)
- 1 application : pbzip2 (parallel bzip2)
- 1 data set : encoded film (1.4 GB) (worst scenario)
- From 1 process to 80 process
- Metrology Tool : time
- Observable : elapsed

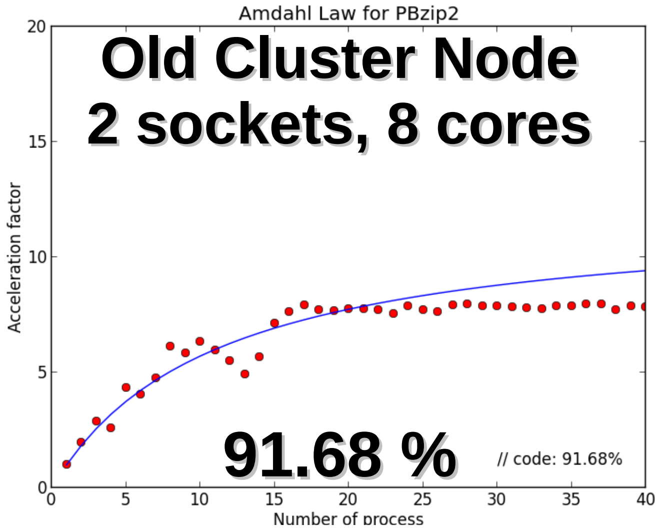


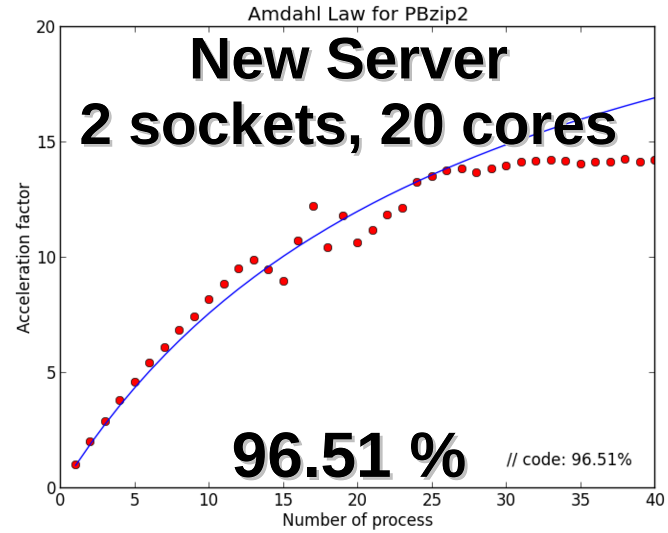
Amdahl Law in real world Acceleration & Variations

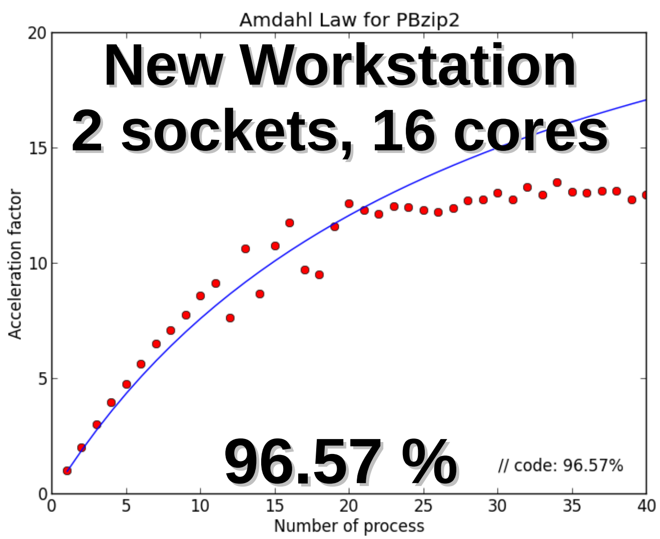
- Symptoms :
  - On large number of cores, 70 % to 80 % efficiency
  - Great variations on recent twice-sockets machines
  - Decrease for heavy charges on old processors

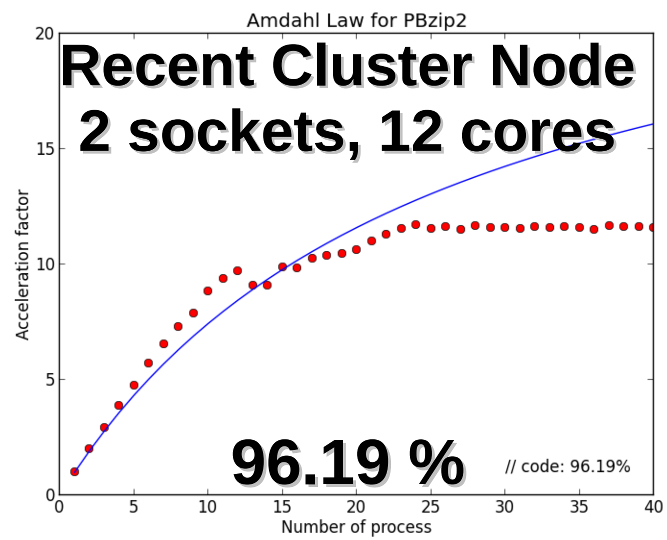


Amdahl Law : Fitting images !

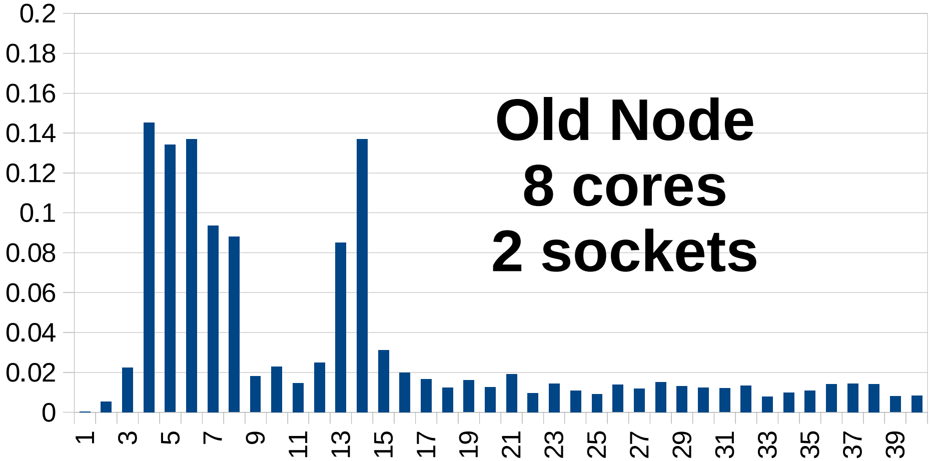


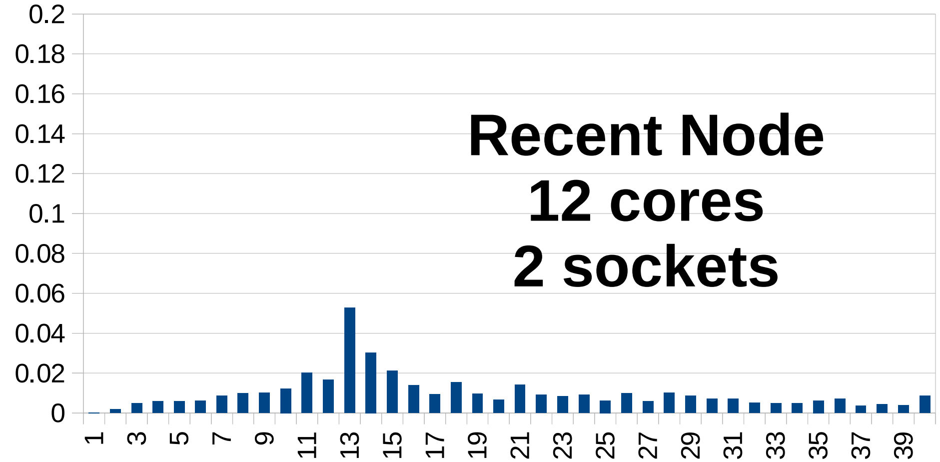


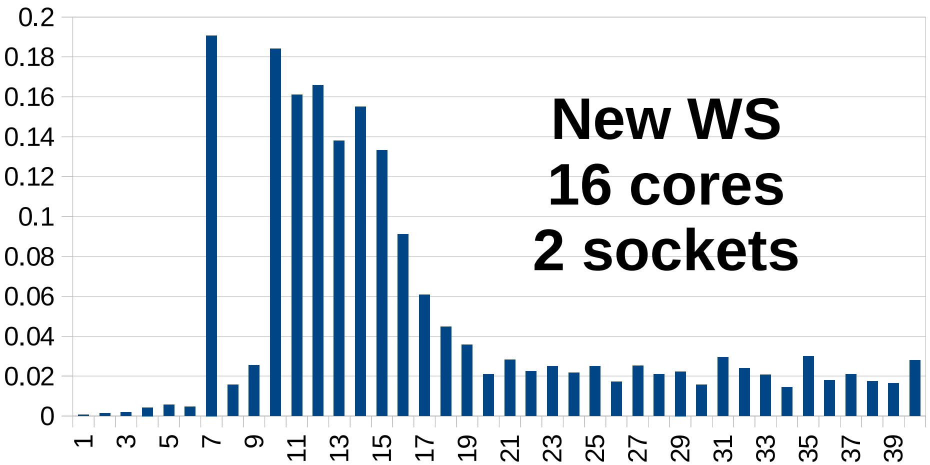


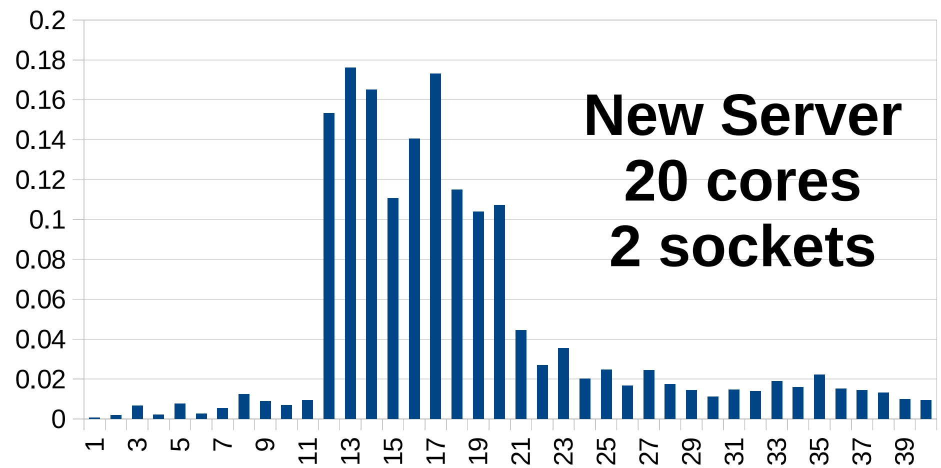


And worse : variability
Variability = Stddev/Median

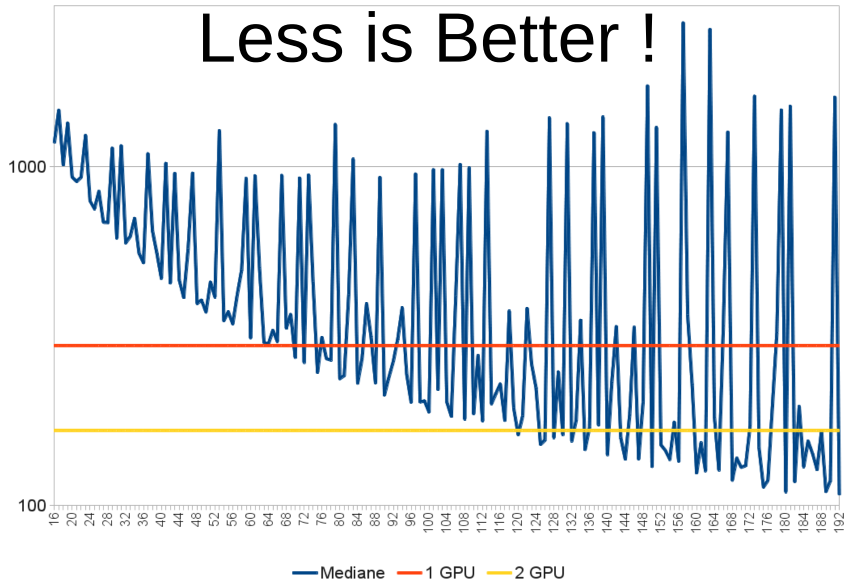






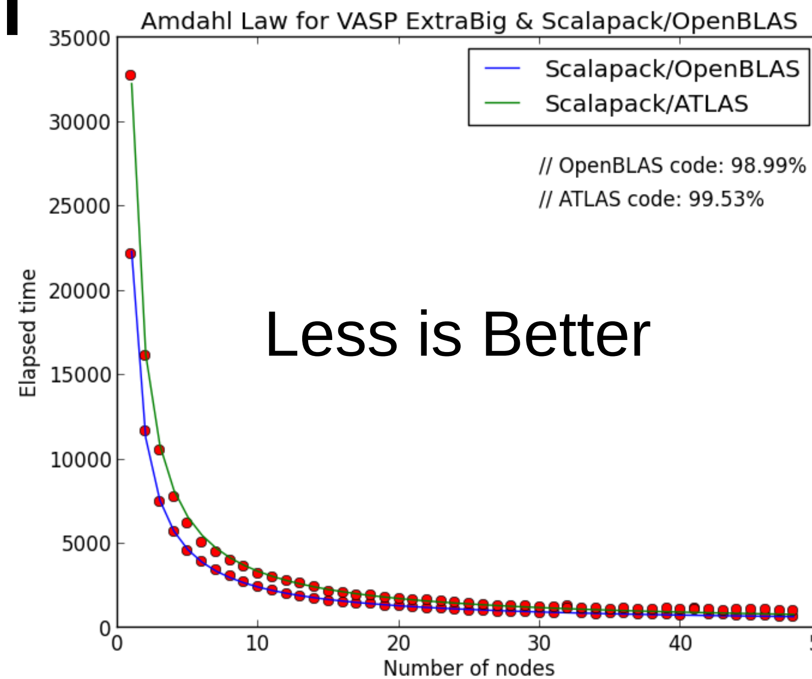


MPI applications, back to science Amdahl law, in real



Lammps Molecular Dynamics application

- From 16 to 192 NP
- Compared to GPGPU
- 99.96 % //ized (personal record!)
- 2GPGPU equal 120 NP

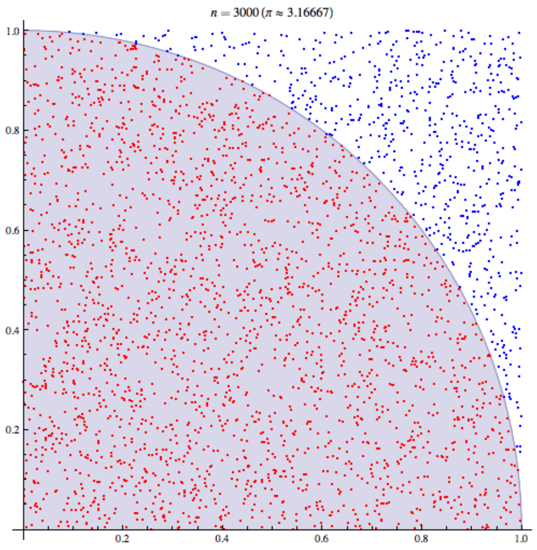


VASP DFT application

- From 1 to 48 NP
- 99 % to 99.5 % //ized
- OpenBLAS vs ATLAS...

What for simplistic implementations ? PiMC : Pi by Dart Board Method

- Historical exemple for Monte Carlo Method : distribution
- Parallel implementation : distribution
  - From 2 to 4 parameters
    - Number of iterations
    - Parallel rate
    - (Type of variable : INT32, INT64, FP32, FP64)
    - (RNG : MWC, CONG, SHR3, KISS)
  - 2 simple observables :
    - Pi estimation (just indicative, Pi not rational :-))
    - Elapsed time



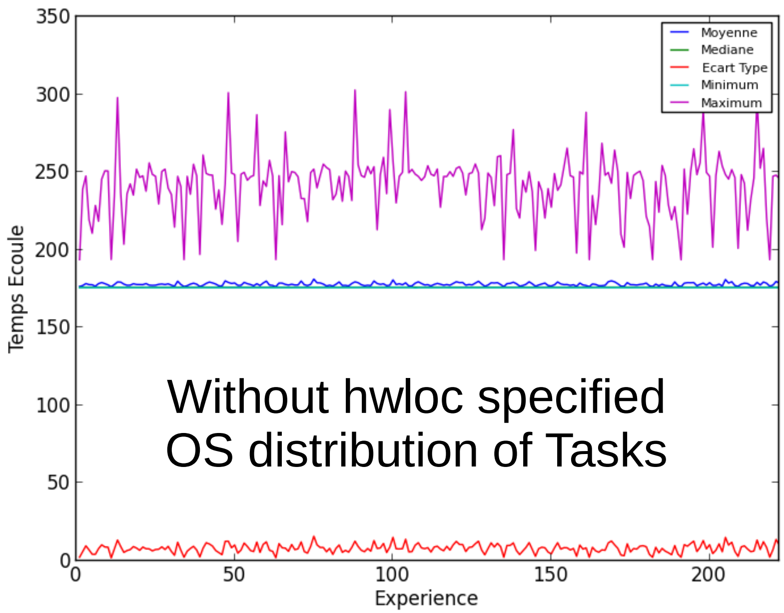
PiMC just for Houches 6th school

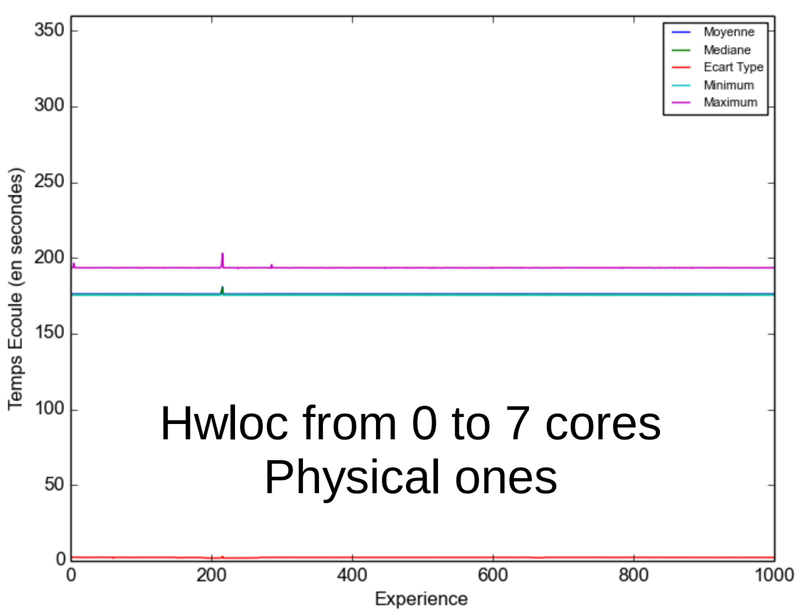
- Bench :
  - Hardware : 64 R410 with 8 cores in HT mode, Infiniband Interconnect
    - Infiniband interconnect
  - OS : Debian Jessie SIDUS
  - Software : OpenMPI/C

- Experiences :
  - Communications reduced to minimum
  - 1 Piterations : 10^{12} equally distributed
  - Parallel rate from 1 to 512 (sparse distribution)
  - 40 launches for each Parallel Rate selected
  - Metrology done by « time » program
  - /usr/bin/time mpirun.openmpi -np $PR -mca btl self,openib,sm -hostfile $MyHostFile -loadbalance hwloc-bind -p pu:$AFF /scratch/root/bench4gpu/Pi/C/MPI/Pi_MPI_FP32_MWC $ITERATIONS

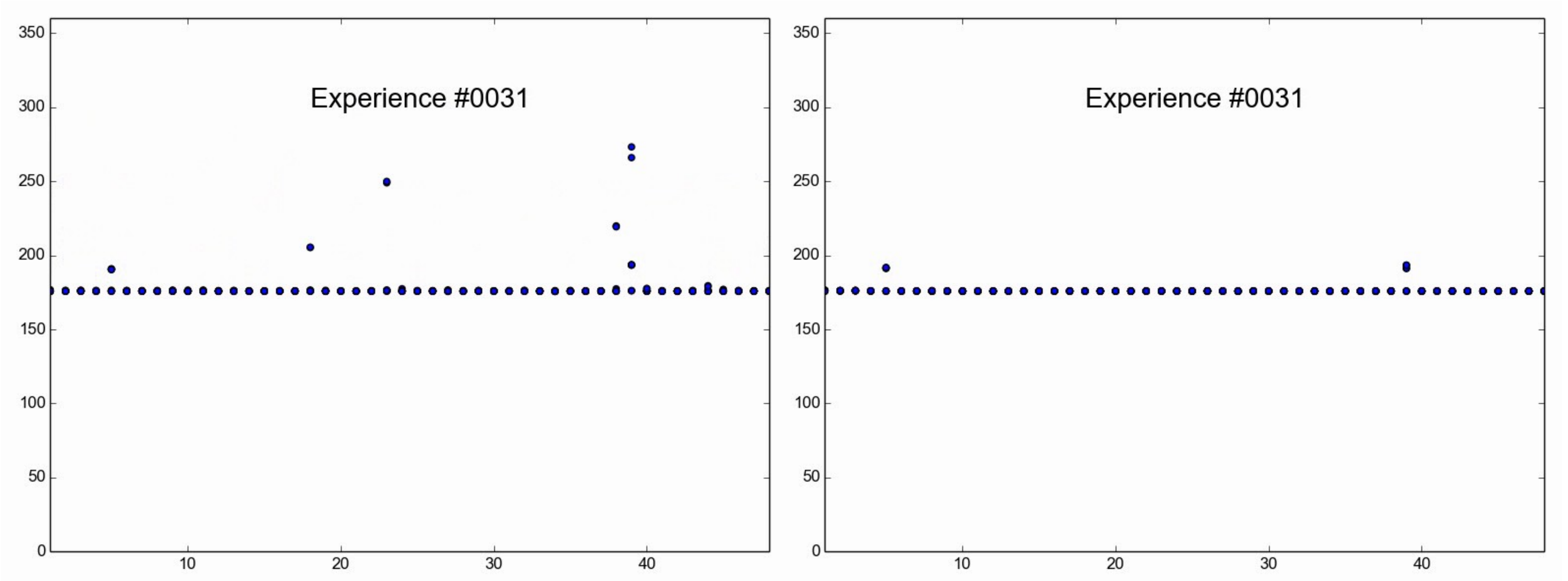
PiMC : why « affinity » selected ?

- During qualification of 48 nodes cluster
- Hundred of launches to evaluate reproducibility
- Morality : localize your process can be useful !





PiMC : why « affinity » selected ? Elapsed time on 48 nodes



No affinity selected

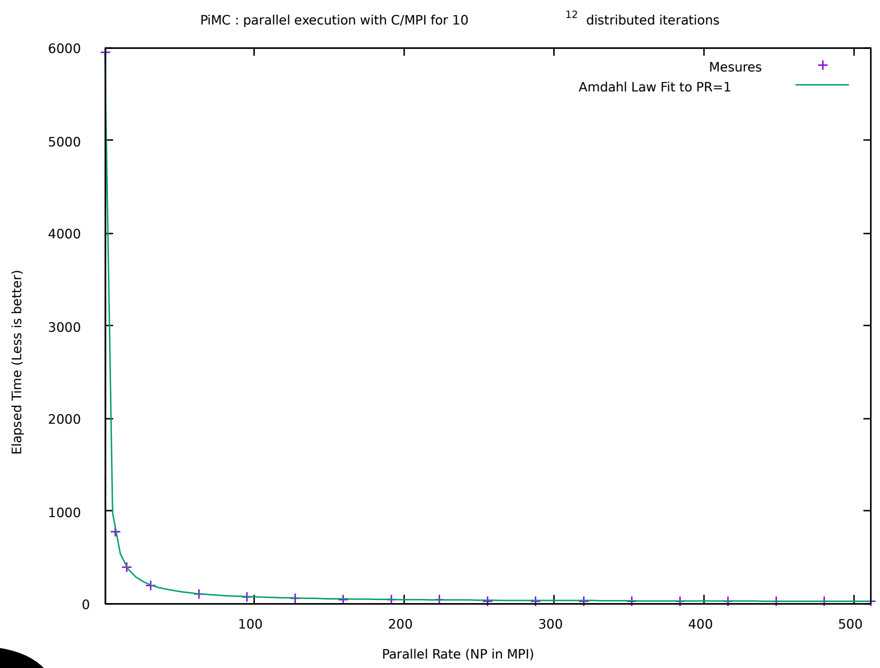
Affinity on first 8th cores

PiMC : and the results are...

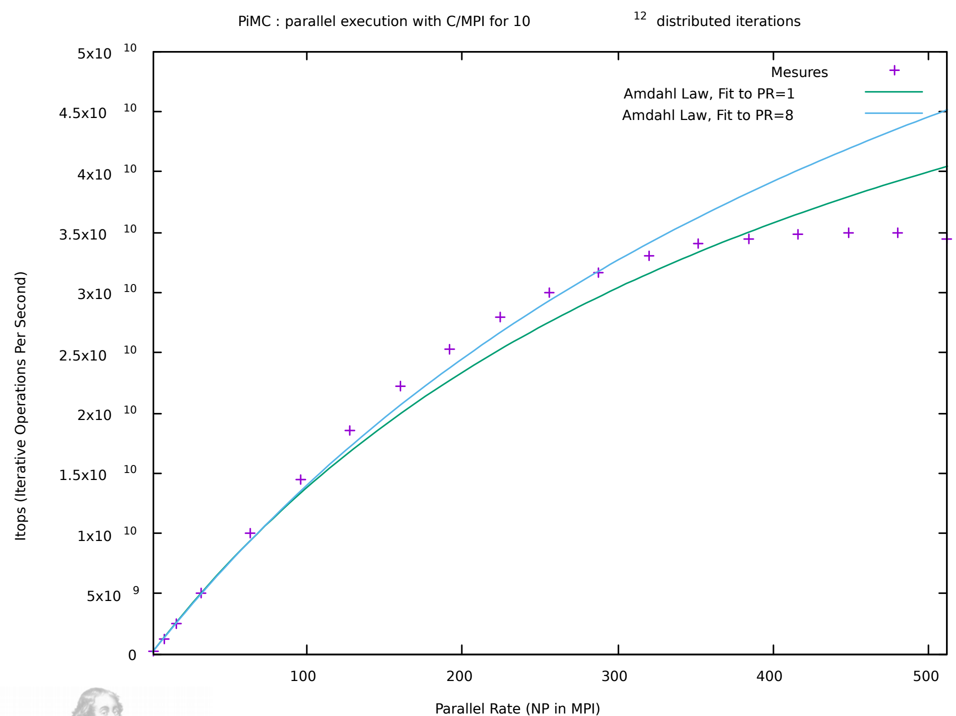
NP	Itops	Speedup 1	Speedup 8	Total Time	Variability %	Average	Median	Stdev	Minimum	Maximum
1	1.68E+08	1.00	1.05	5952	0.04	5953.22	5952.11	2.46	5950.32	5958.86
8	1.28E+09	7.62	8.00	6245	0.05	780.54	780.65	0.35	780.02	781.05
16	2.55E+09	15.21	15.96	6263	0.04	391.41	391.41	0.16	391.04	391.71
32	5.08E+09	30.22	31.71	6302	0.07	196.95	196.93	0.13	196.82	197.53
64	9.96E+09	59.30	62.22	6424	0.08	100.39	100.38	0.08	100.25	100.63
96	1.45E+10	86.31	90.56	6621	0.25	68.94	68.97	0.18	68.32	69.53
128	1.86E+10	110.86	116.32	6872	0.55	53.75	53.69	0.29	53.14	54.74
160	2.22E+10	132.12	138.63	7208	0.75	45.09	45.05	0.34	44.47	46.28
192	2.53E+10	150.53	157.95	7592	0.59	39.52	39.54	0.23	38.85	40.20
224	2.80E+10	166.38	174.57	8014	0.81	35.80	35.78	0.29	35.21	37.10
256	3.00E+10	178.80	187.60	8522	0.74	33.32	33.29	0.25	32.78	34.28
288	3.17E+10	188.54	197.82	9092	0.82	31.58	31.57	0.26	31.04	32.30
320	3.30E+10	196.28	205.94	9704	1.04	30.37	30.33	0.31	29.87	31.26
352	3.40E+10	202.14	212.10	10365	1.43	29.52	29.45	0.42	28.83	30.58
384	3.44E+10	204.86	214.94	11157	1.29	29.08	29.06	0.38	28.34	30.19
416	3.48E+10	207.14	217.34	11954	1.03	28.70	28.74	0.30	28.19	29.67
448	3.50E+10	208.08	218.32	12815	1.16	28.67	28.61	0.33	28.04	29.69
480	3.49E+10	207.97	218.21	13738	1.34	28.65	28.62	0.38	27.99	29.77
512	3.45E+10	205.10	215.20	14858	1.28	29.10	29.02	0.37	28.58	30.18

PiMC : graphically
Does really Amdahl a good law ?

- Elapsed Time in seconds
  - Seems to be nice, but…

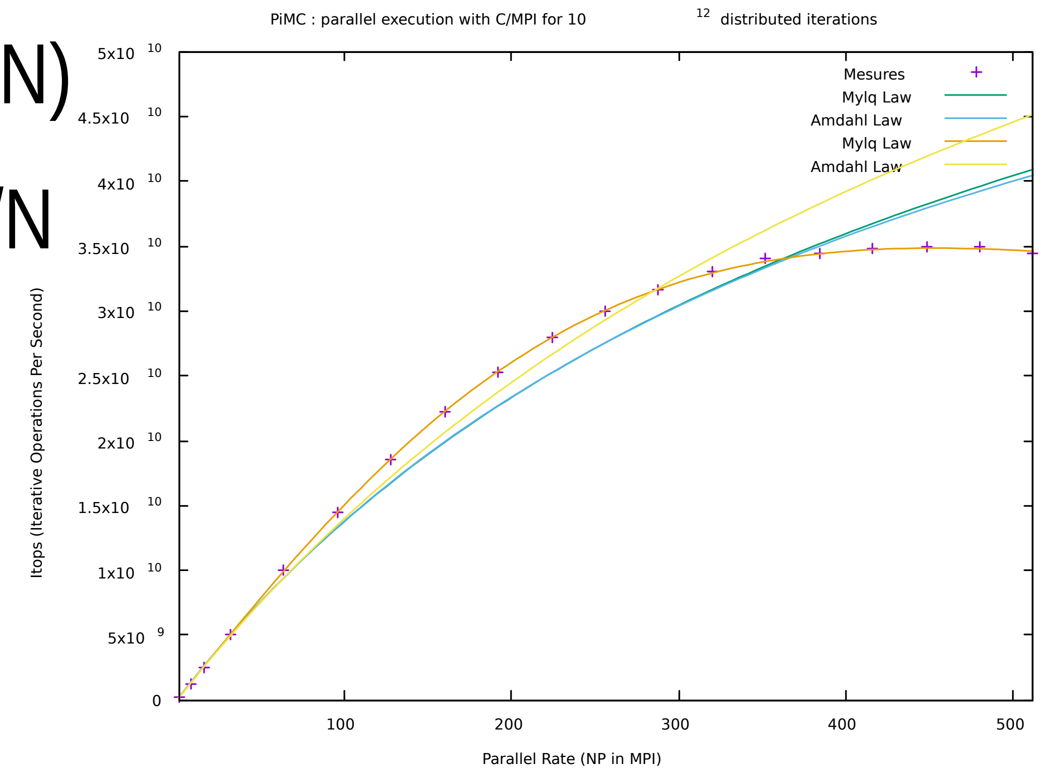


- Performance in Itops
  - Fit to 1 : p=99.78 %
  - Fit to 8 : p=99.83 %



Evolution of Amdahl law : Integer a linear influence : Mylq

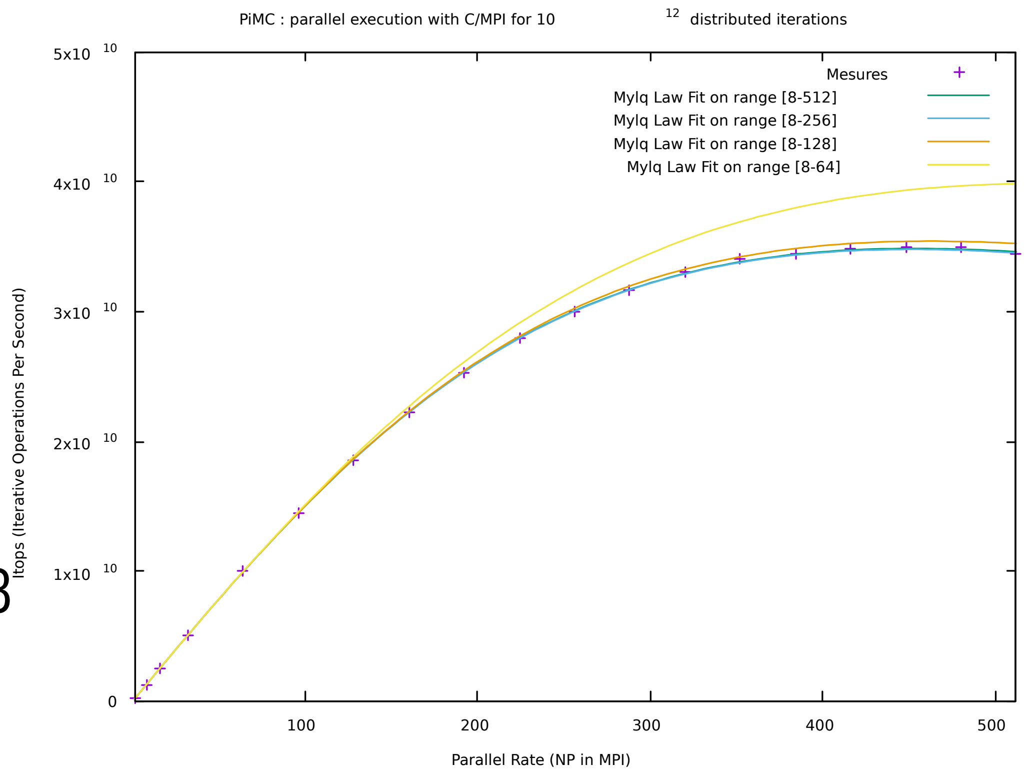
- Amdahl law : $T=T_1(1-p/p/N)$
- Mylq law : $T=s_M+c_MN+p_M/N$
- Signification c_M :
  - Communications
  - Initialization processes
  - and c_M~0.03,



- And p_M ~ 0.9998 with a fit which excludes PR=1 value

Mylq Law : Why exclude PR=1 Is a better predictible law ?

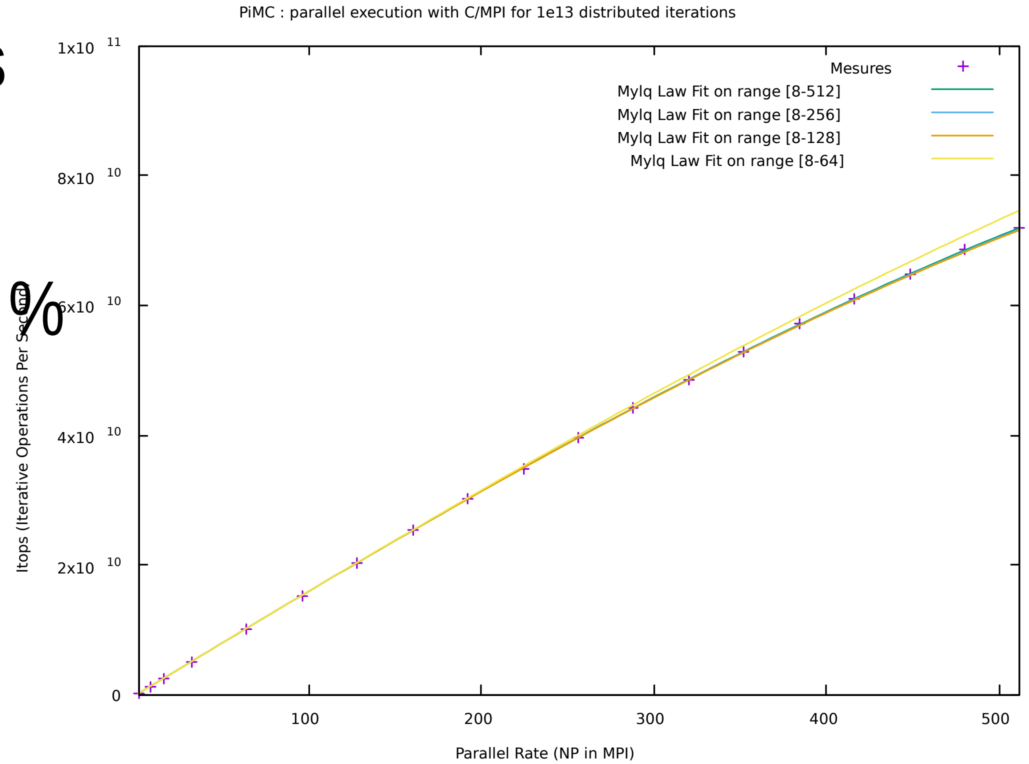
- Why exclude PR=1
  - Internal node mecanisms
  - OS effects
  - Processor effects : Turbo
- More predictible law ?
  - Try to fit with only : 1/2,1/4,1/8
  - On 1/4, it works fine ;-)



- But there are other effects to include...

Influence of Elapsed time And if I inscrease iterations ?

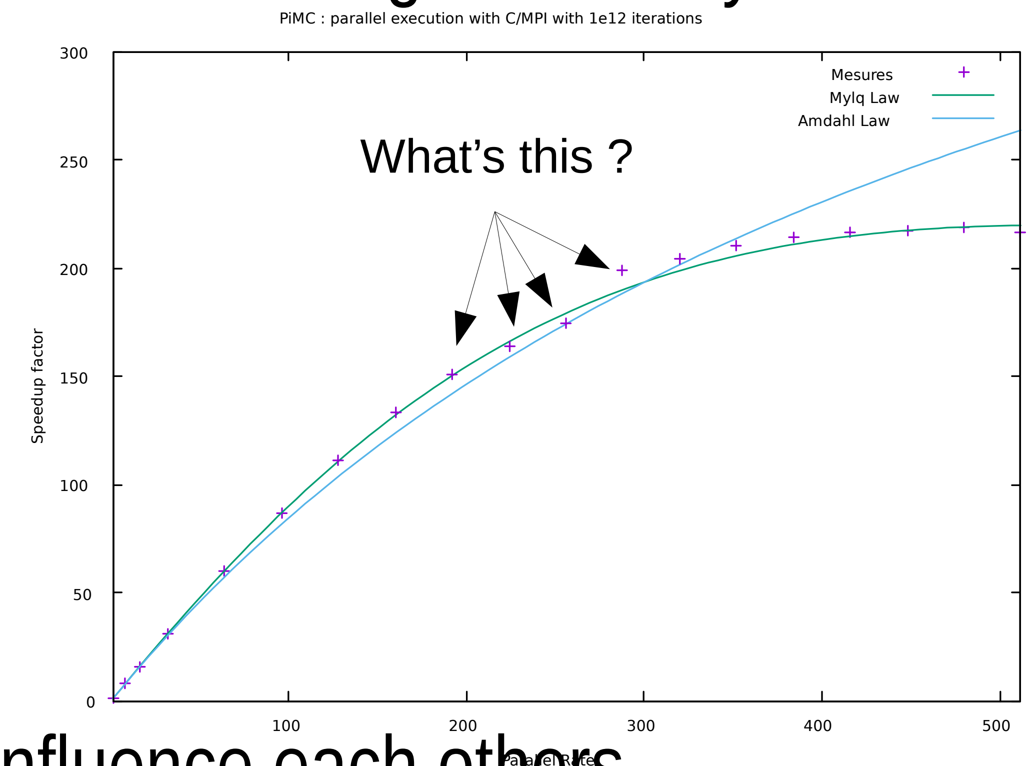
- From 10^{12} to 10^{13} iterations
- Speedup from 208 to 448
- Efficiency from 40 % to 87 %
- Itops from 34 to 72 Gitops
- Mylq Parameters :
  - p_M reduced of 0.99998
  - c_M=0.032 (previous 0.03)



- Morality : don't be to stingy on your test sets ;-)

Why previous conclusions are not really honest...

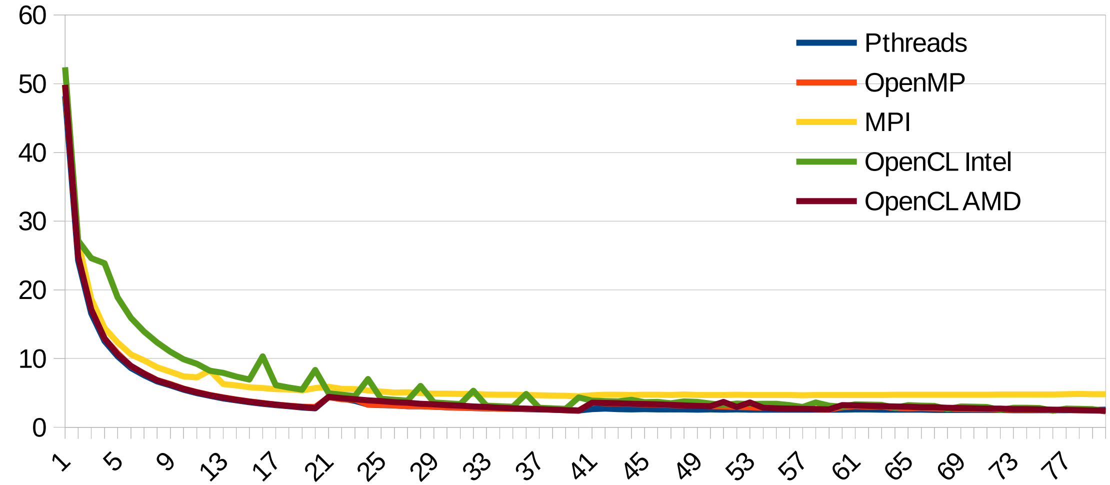
- Few days before, Mylq fit was not so good… Why ?
  - Lack of statistics ?
    - For each PR, 10 runs
    - Distribute on 64-nodes
      - Concurrent jobs
      - Exclusive in parts
    - Variability around 1 %
  - Solution :
    - Exclusive runs in time

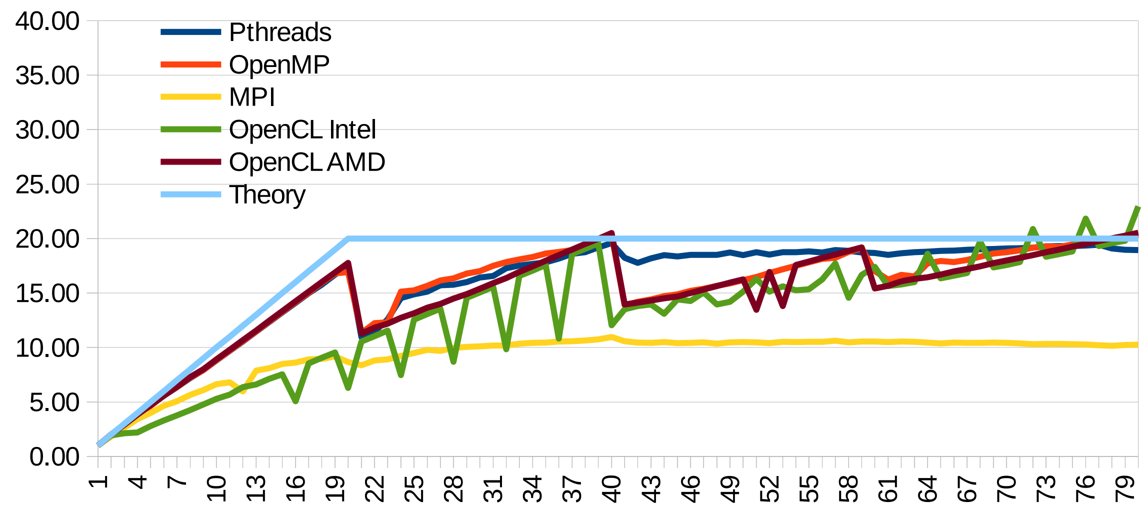


- So, coarse grain codes influence each others...

What about other parallelisms ?
It's worse… Small example

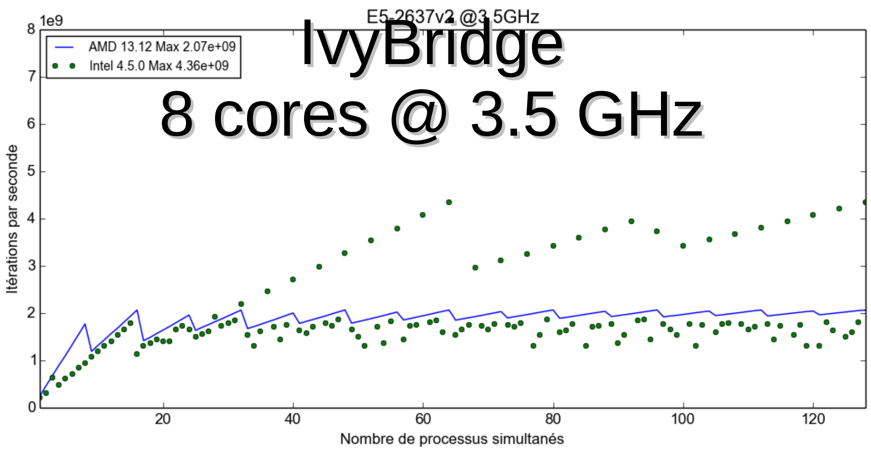
- Let's return inside the node…
- A Dell server PowerEdge R620
  - Bi-socket, 10-cores : 20 cores
  - Hyperthreading mode activated : 40
- Parallel implementations
  - MPI in C
  - OpenMP in C
  - Pthreads in C
  - OpenCL in Python
    - OpenCL by AMD
    - OpenCL by Intel
- Finalement, pas mal OpenCL !



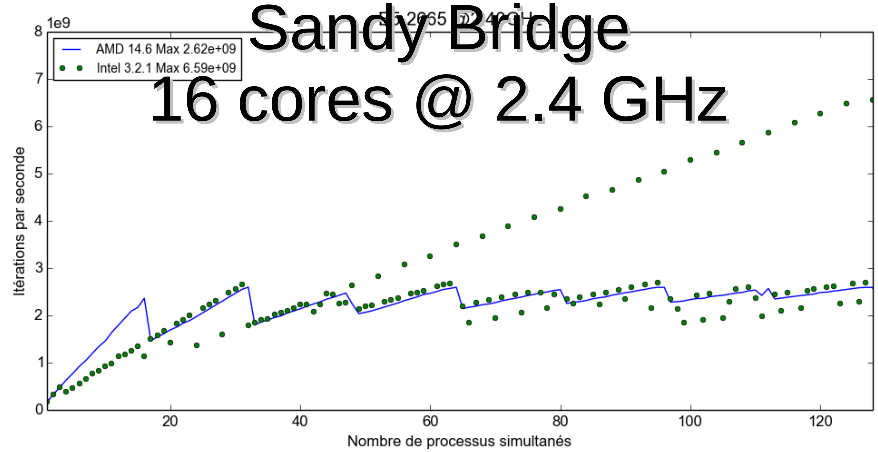


Ok, but for other processors ? Mmmm... Interesting...

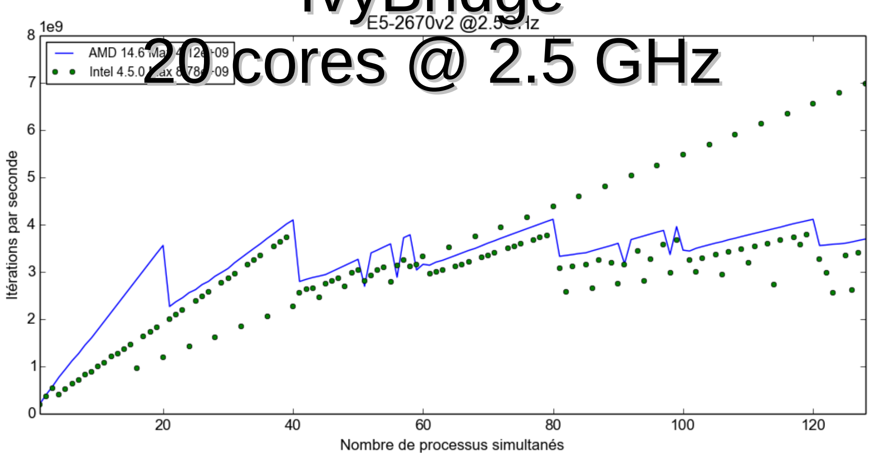
IvyBridge
8 cores @ 3.5 GHz



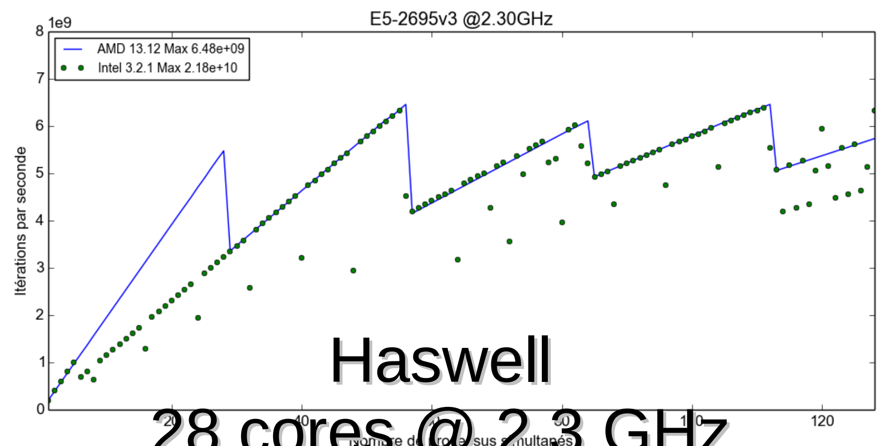
Sandy Bridge
16 cores @ 2.4 GHz



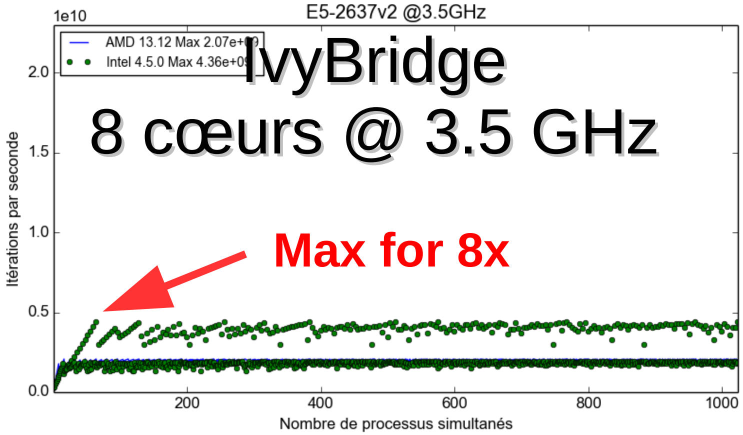
IvyBridge
20 cores @ 2.5 GHz

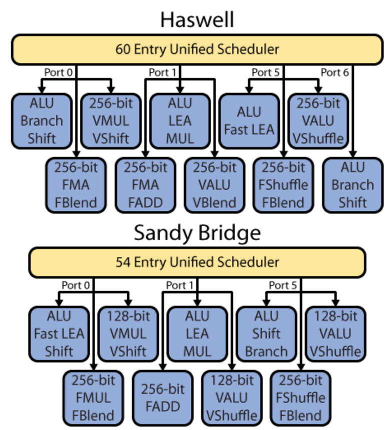


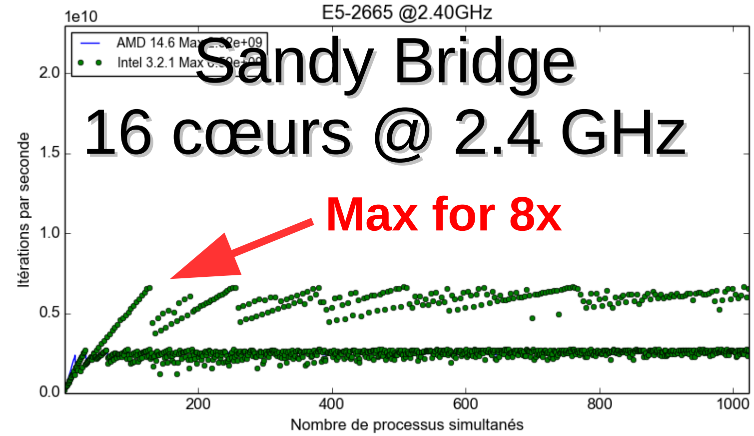
Haswell
28 cores @ 2.3 GHz

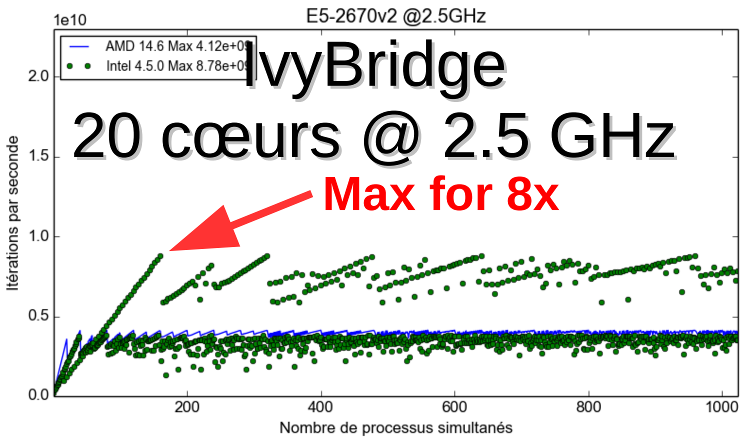


And for PR >> Number of cores
EPU depends of architecture !



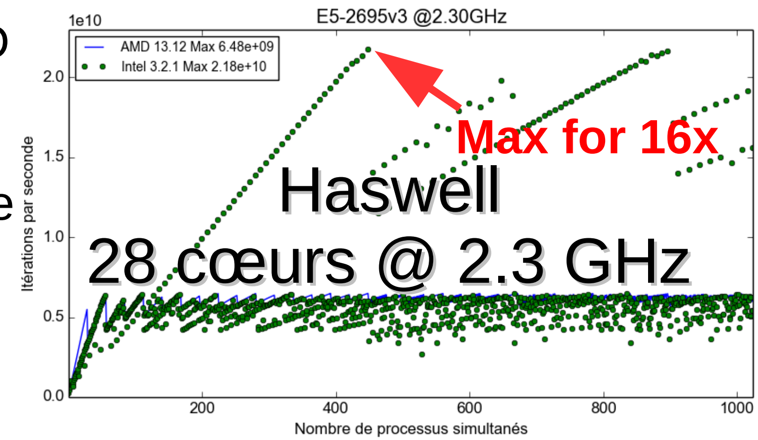




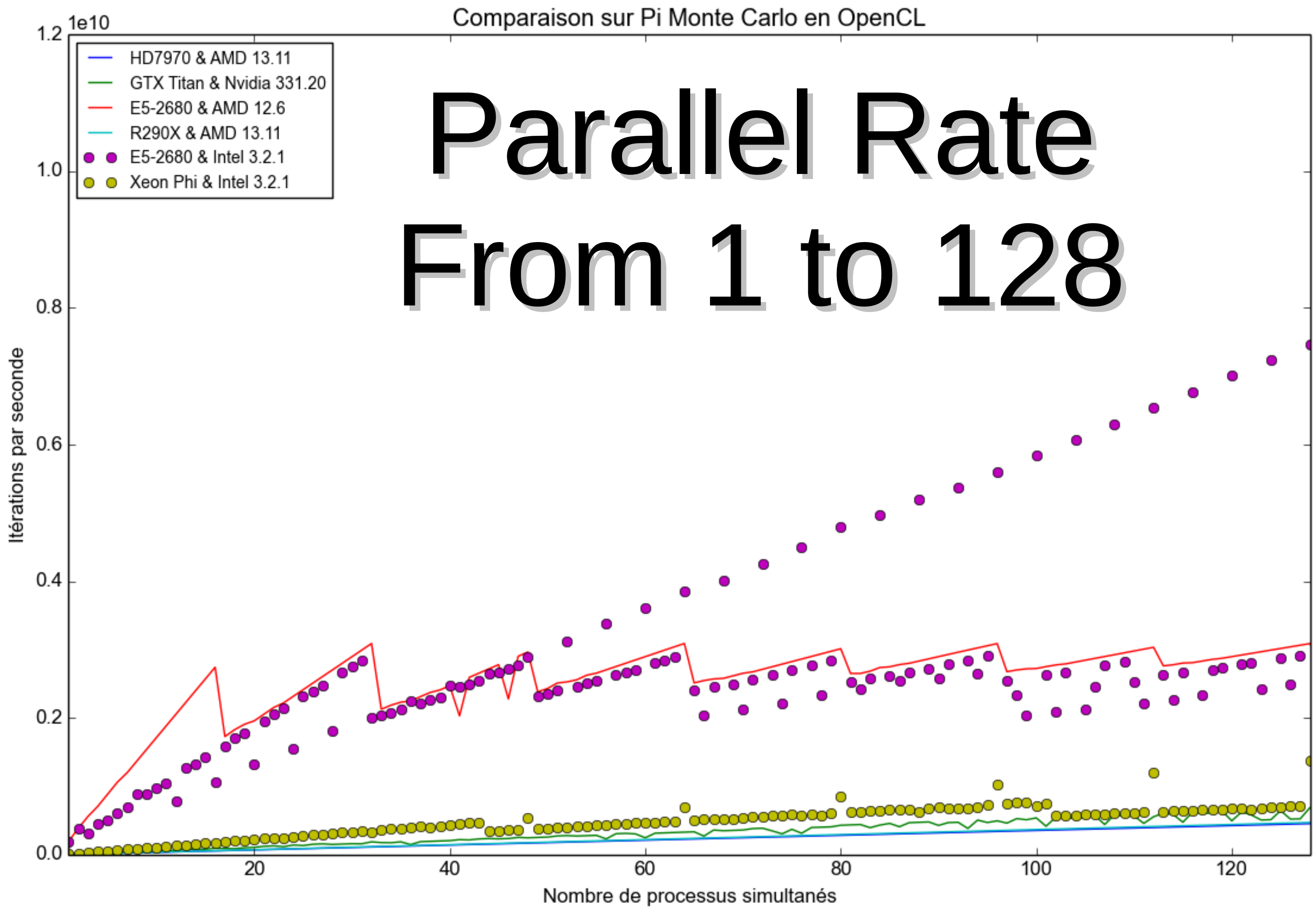


Intel x2,3 vs AMD
Period of 4
Max Perf :

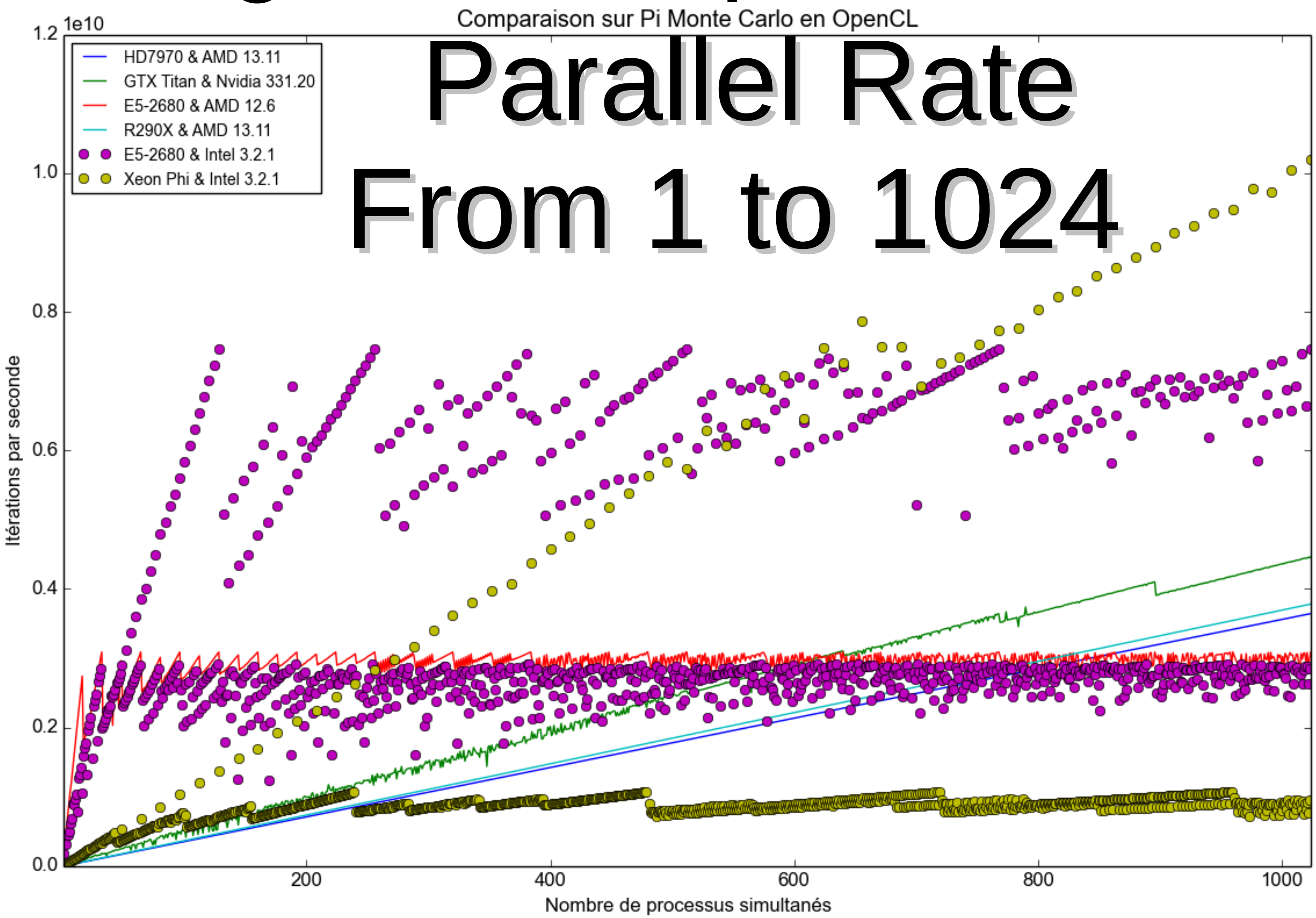
- x8 Sandybridge
- x8 IvyBridge
- x16 Haswell



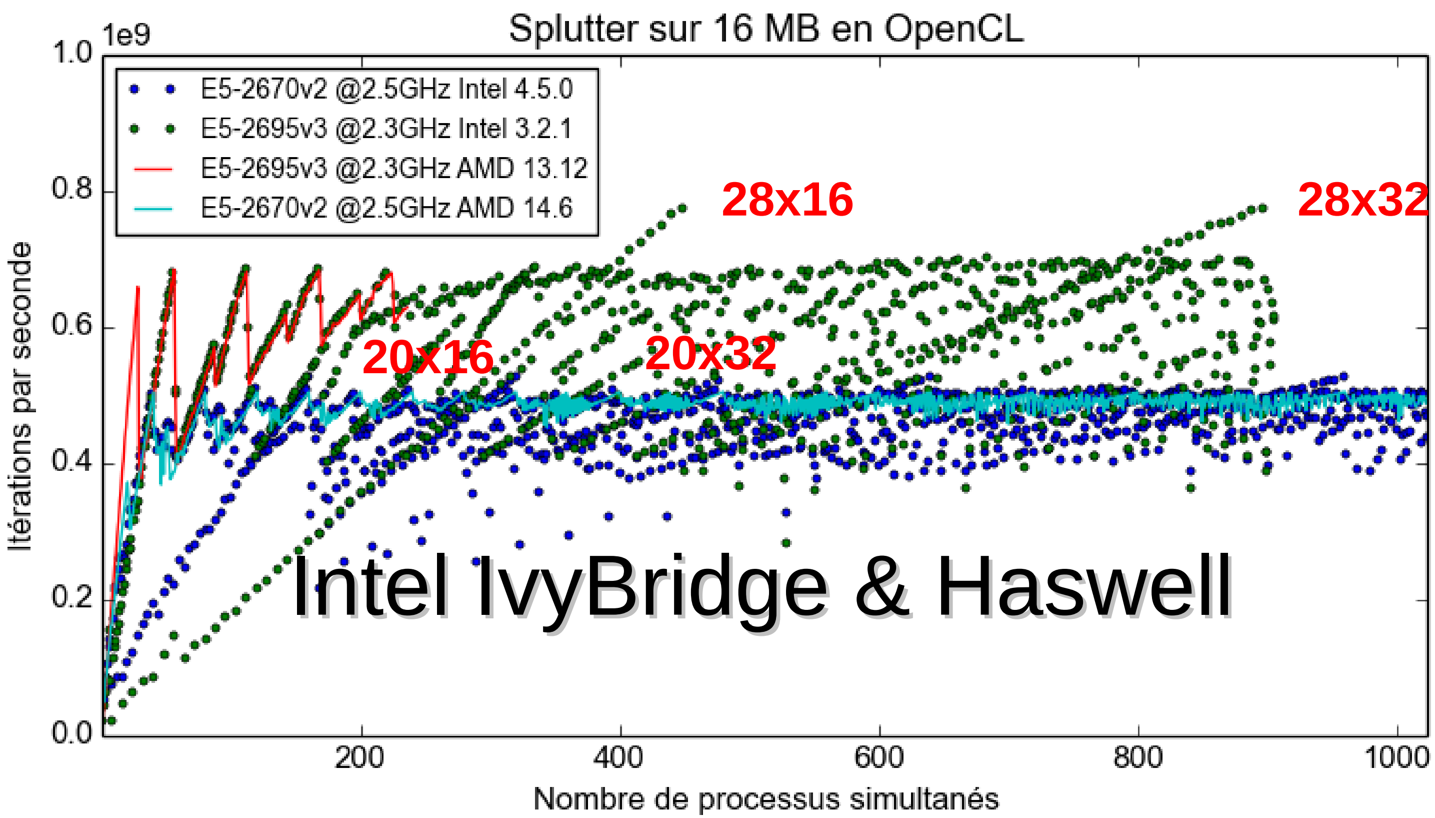
And for others architectures Mouth-watering before tomorrow



And for others architectures
Increasing PR to explore...



After, *PU bound, Memory Bound
The « splutter » to stress memory



Introduction to conclusion : IT : The new world of complexity

- Complicated : from « cum plicare », « fold together »
  - Descartes : « All is the sum of parts. »
- Complex : from « cum plexus », « weave together »
  - Huge amount of interactions, non linearity, emergence, ...
- Computing resources are complex systems
  - A running Operating System has at least 200 process running background
  - CPU cores change frequency & voltage all the time, start/stop, …
  - DRAM change frequency all the time
  - Communication devices (network) are all random access components

OSI Model & Amdahl Law Evolutions & perspectives

- OSI Model : Layer below seen as a service
  - Ignoring all the infrastructure is clearly a suicide for scalability
- Amdahl Law : Only depends of T_1 and p
  - It cannot be used...
- Mylq Law : add a simple proportional factor
  - Can help you to evaluate scalabity and predictive performance
- Inside a node, nothing works
  - And in a GPU or accelerator