Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

Extrae & Paraver Hands-On

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POP Performance Analysis

Extrae features

- Platforms
  - Intel, Cray, BlueGene, MIC, ARM, Android, Fujitsu Sparc …
- Parallel programming models
  - MPI, OpenMP, pthreads, OmpSs, CUDA, OpenCL, Java, Python …
- Performance Counters
  - Using PAPI interface
- Link to source code
  - Callstack at MPI routines
  - OpenMP outlined routines
  - Selected user functions (Dyninst)
- Periodic sampling
- User events (Extrae API)

No need to recompile or relink!

How does Extrae work?

- Symbol substitution through LD_PRELOAD
  - Specific libraries for each combination of runtimes
    - MPI
    - OpenMP
    - OpenMP+MPI
    - …

Recommended

- Dynamic instrumentation
  - Based on Dyninst (developed by U.Wisconsin / U.Maryland)
    - Instrumentation in memory
    - Binary rewriting

- Alternatives
  - Static link (i.e., PMPI, Extrae API)

Using Extrae in 3 steps

1. **Adapt** your job submission scripts
2. **Configure** what to trace
   - XML configuration file
   - Example configurations at `$EXTRAE_HOME/share/example`
3. **Run** it!

- For further reference check the **Extrae User Guide:**
  - https://tools.bsc.es/doc/html/extrae
  - Also distributed with Extrae at `$EXTRAE_HOME/share/doc`

Log in to Jusuf

```
laptop$ ssh -Y <USER>@jusuf.fz-juelich.de
```

- The following directory contains all the examples:

```
jusuf$ cp -r /p/project/training2214/tools-material
$HOME
   jusuf$ ls -l $HOME/tools-material
   bin/
   clustering/
   extrae/
   slides/
   traces/
```

Here you have a copy of this slides.
Copy them to your laptop
or open remotely with:

```
> evince slides/Extrae-Paraver-Hands-On.pdf
```

Step 1: Adapt the job script to load Extrae

```
jusuf$ vi $HOME/tools-material/extrae/job_27p.sh
```

```
#!/bin/bash -x
#SBATCH --account=training2214
#SBATCH --nodes=1
#SBATCH --ntasks=27
#SBATCH --cpus-per-task=1
#SBATCH --output=lulesh2.0_27p.%j
#SBATCH --error=lulesh2.0_27p.%j
#SBATCH --time=00:10:00
#SBATCH --partition=batch

export OMP_NUM_THREADS=${SLURM_CPUS_PER_TASK}

srun --cpu-bind=cores ../bin/lulesh2.0 -i 10 -s 65 -p
```

Request resources

Run the program

Step 1: Adapt the job script to load Extrae

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```
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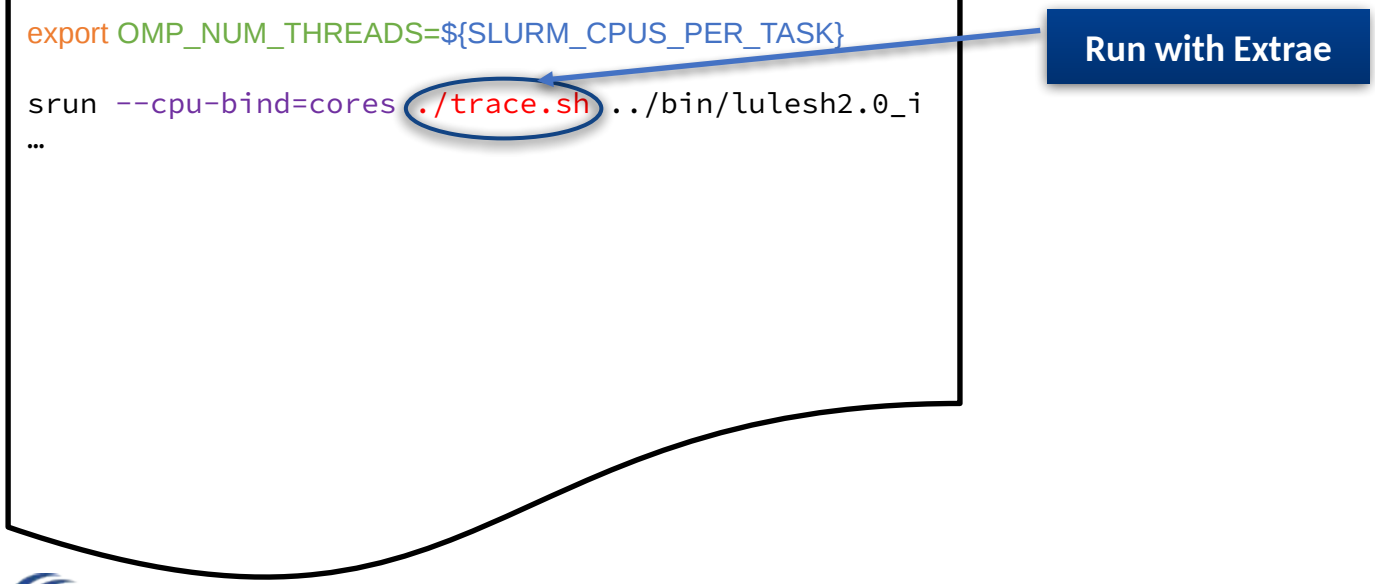
#SBATCH --error=lulesh2.0_27p.%j
#SBATCH --time=00:10:00
#SBATCH --partition=batch

export OMP_NUM_THREADS=${SLURM_CPUS_PER_TASK}

srun --cpu-bind=cores ./trace.sh ../bin/lulesh2.0_i
…
```



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#SBATCH --error=lulesh2.0_27p.%j
#SBATCH --time=00:10:00
#SBATCH --partition=batch

export OMP_NUM_THREADS=${SLURM_CPUS_PER_TASK}


srun --cpu-bind=cores ./trace.sh ../bin/lulesh2.
…
```

```
#!/usr/bin/env bash

module load GCC ParaStationMPI Extrae

export
EXTRAE_HOME=/p/software/jusuf/stages/2022/softwar
e/Extrae/3.8.3-gpsmpi-2021b

export TRACE_NAME=lulesh2.0_27p.prv

# Configure Extrae
export EXTRAE_CONFIG_FILE=extrae.xml

# Load the tracing library (choose C/Fortran)
export LD_PRELOAD=$EXTRAE_HOME/lib/libmpitrace.so
#export
LD_PRELOAD=$EXTRAE_HOME/lib/l

# Run the program
$*
```

Load Extrae

What to trace?

Type of application

Step 1: Which tracing library?

- Choose depending on the application type

Library	Serial	MPI	OpenMP	pthread	CUDA
libseqtrace	x				
libmpitrace[f][1]		x			
libomptrace			x		
libpttrace				x	
libcudatrace					x
libompitrace[f] [1]		x	x		
libptmpitrace[f] [1]		x		x	
libcudampitrace[f] [1]		x			x

[1] include suffix "f" in Fortran codes

Step 2: Extrae XML configuration

```
jusuf$ vim $HOME/tools-material/extrae/extrae.xml
```

```
<mpi enabled="yes">
  <counters enabled="yes" />
</mpi>

<openmp enabled="no">
  <locks enabled="no" />
  <counters enabled="yes" />
</openmp>

<pthread enabled="no">
  <locks enabled="no" />
  <counters enabled="yes" />
</pthread>

<callers enabled="yes">
  <mpi enabled="yes">1-3</mpi>
  <sampling enabled="no">1-5</sampling>
</callers>
```

Trace the MPI calls
(What's the program doing?)

Trace the call-stack
(Where in my code?)

Step 2: Extrae XML configuration (II)

```
jusuf$ vi $HOME/tools-material/extrae/extrae.xml
```

```
<counters enabled="yes">
    <cpu enabled="yes" starting-set-distribution="1">
      <set enabled="yes" domain="all" changeat-time="0">
        PAPI_TOT_INS,PAPI_TOT_CYC
      </set>
    </cpu>
    <network enabled="no" />
    <resource-usage enabled="no" />
    <memory-usage enabled="no" />
  </counters>
```

Select which HW counters are measured
(How's the machine doing?)

Step 2: Extrae XML configuration (III)

```
jusuf$ vi $HOME/tools-material/extrae/extrae.xml
```

```
<buffer enabled="yes">
  <size enabled="yes">500000</size>
  <circular enabled="no" />
</buffer>

<sampling enabled="no" type="default" period="50m" variability="10m" />

<merge enabled="yes"
  synchronization="default"
  tree-fan-out="16"
  max-memory="512"
  joint-states="yes"
  keep-mpits="yes"
  sort-addresses="yes"
  overwrite="yes">
  $TRACE_NAME$
</merge>
```

Trace buffer size
(Flush/memory trade-off)

Enable sampling
(Want more details?)

Automatic post-processing to generate the Paraver trace

Step 3: Run it!

- Submit your job

```
jusuf$ cd $HOME/tools-material/extrae
jusuf$ sbatch job_27p.sh
```

- Easy!

All done! Check your resulting trace

- Once finished (check with “squeue”) you will have the trace (3 files):

```
jusuf$ ls -l $HOME/tools-material/extrae
lulesh2.0_i_27p.pcf
lulesh2.0_i_27p.prv
lulesh2.0_i_27p.row
```

- Any trouble? Traces already generated here:

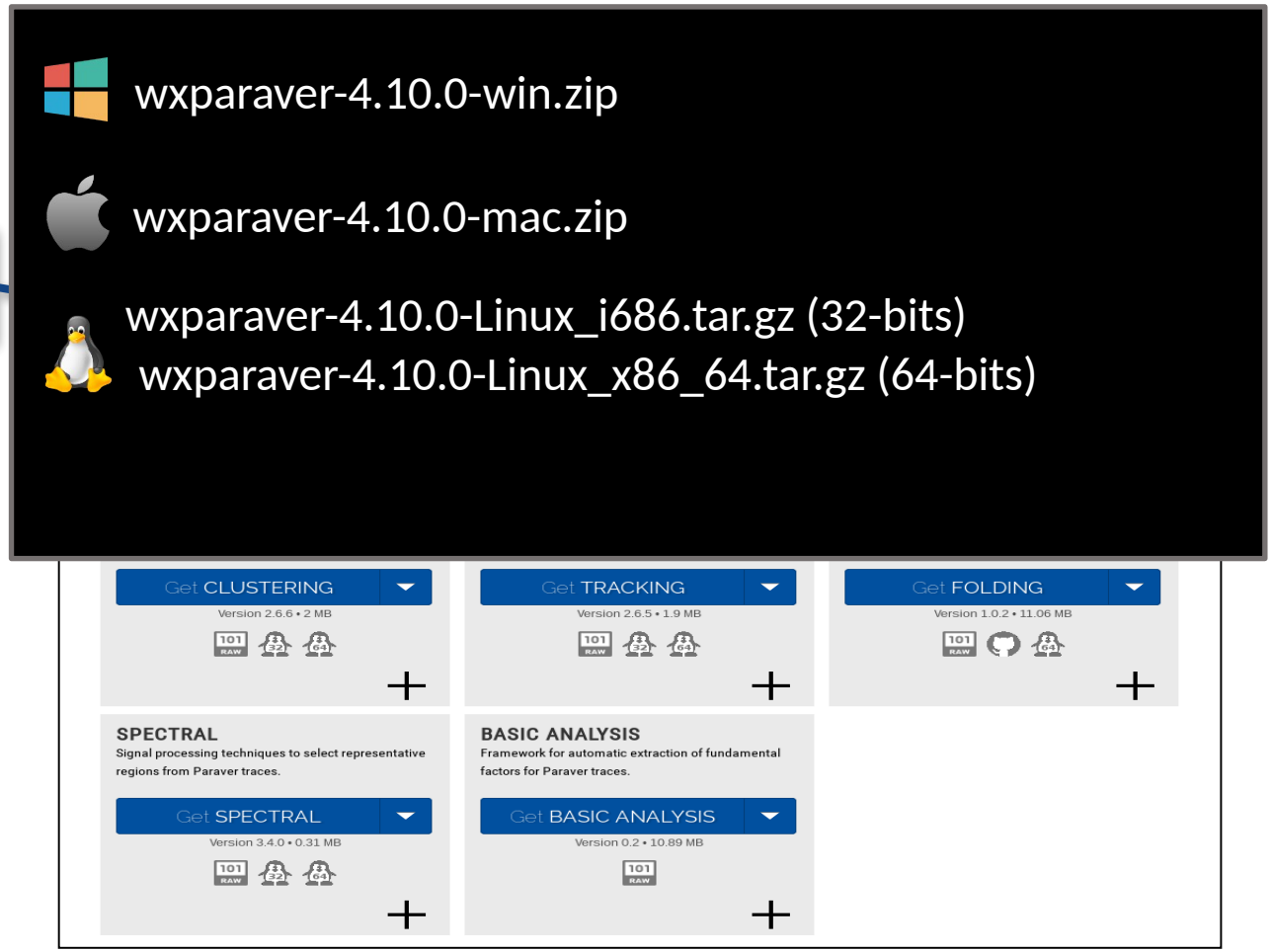
```
jusuf$ ls $HOME/tools-material/traces
```

- Now let’s look into it !

Install Paraver

- Download from https://tools.bsc.es/downloads

Pick your version



Install Paraver (II)

```
laptop$ tar xf wxparaver-4.10.0-linux-x86_64.tar.gz
laptop$ mv wxparaver-4.10.0-linux-x86_64 paraver
```

- Start Paraver

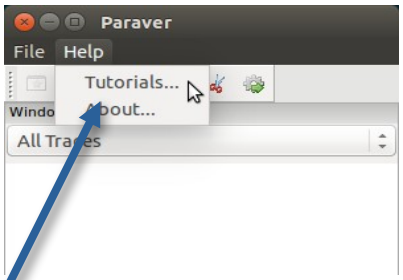
```
laptop$ paraver/bin/wxparaver
```

- Trouble installing locally? Remote open from Jusuf

```
jusuf$ wxparaver
```

Install Paraver tutorials (I)

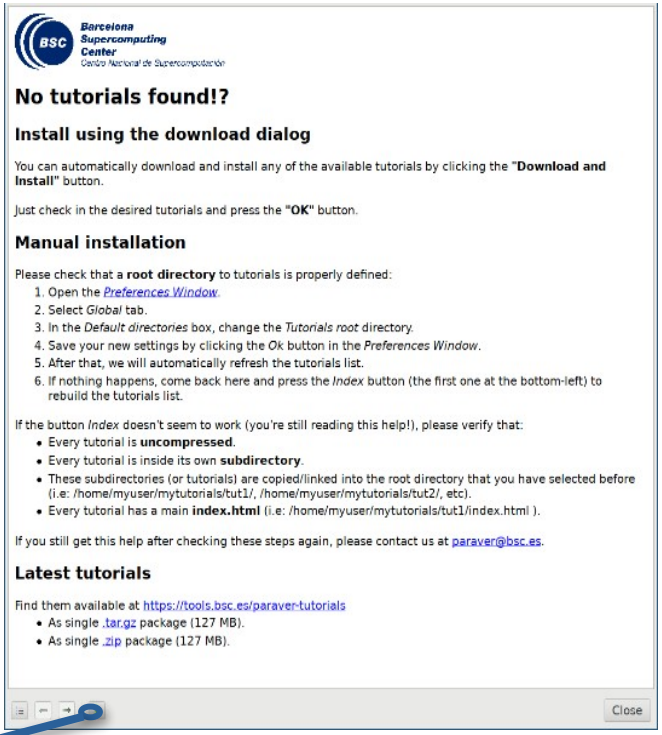
- Download tutorials:



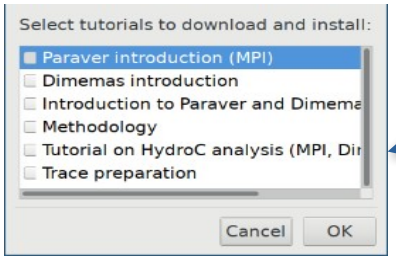
Click on Help → Tutorials

Tutorials window will pop-up

Tutorials



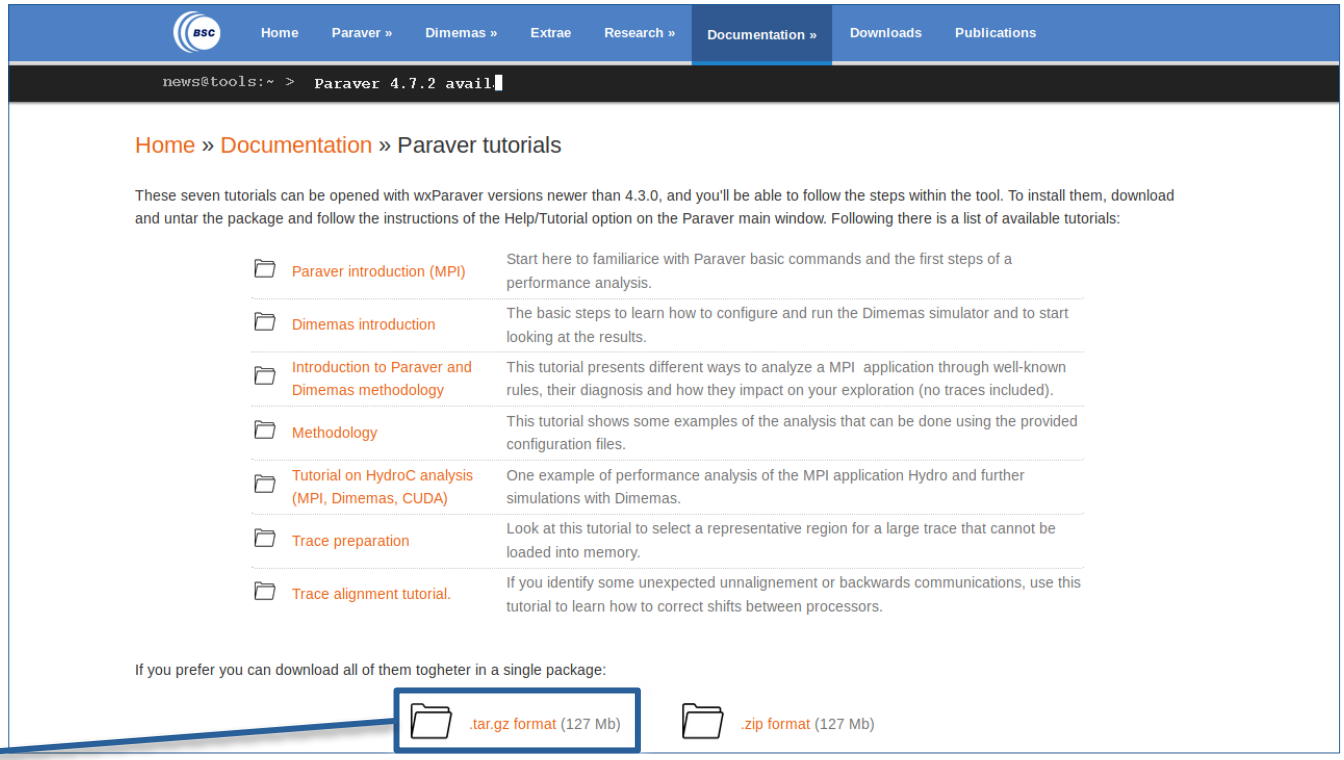
Tutorials down...



Follow these tutorials by clicking on the hyperlinks and reading the explanations. When you click on a link, multiple views will open.

Install Paraver tutorials – alternative methods(II)

- Download tutorials archive
  - https://tools.bsc.es/paraver-tutorials



All tutorials

```
paraver-tutorials-20150526.tar.gz
```

Install Paraver tutorials – alternative methods(III)

- Start Paraver:
  - Linux: Run the command:

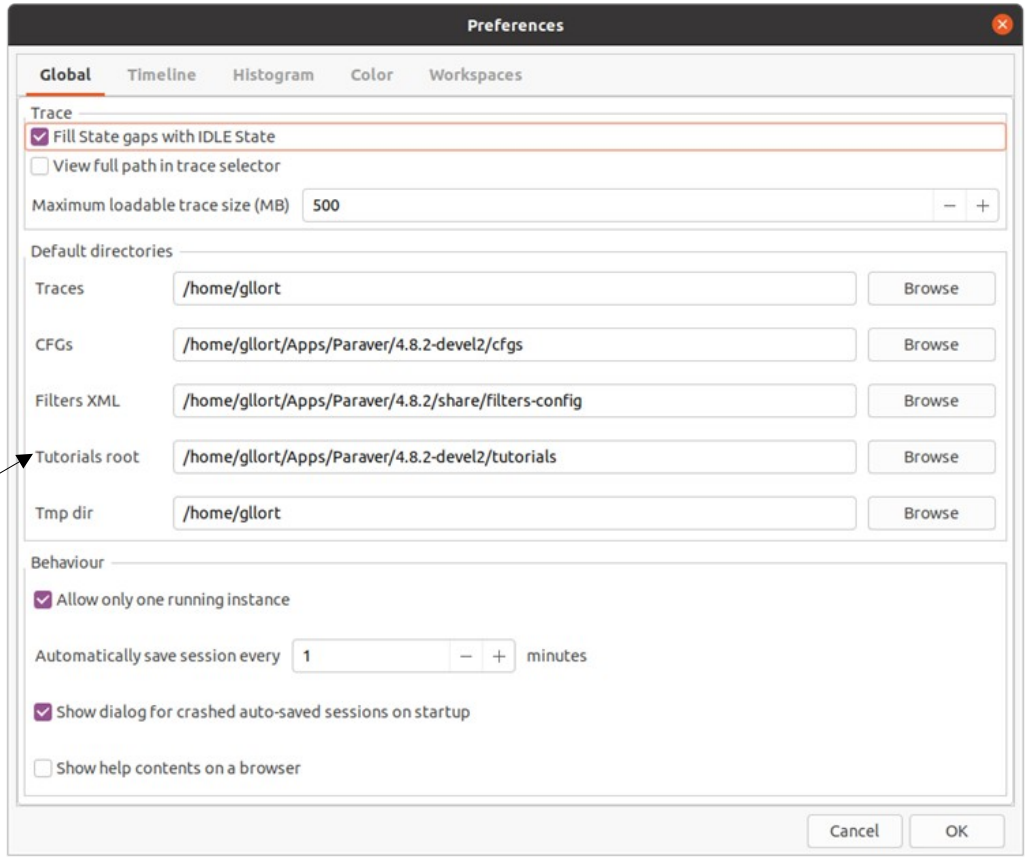
```
laptop$ paraver/bin/wxparaver
```

  - Windows: Double-click on paraver/wxparaver.exe
  - MAC: Double click on paraver/wxparaver.app

- Open File → Preferences

Setup the “Tutorials root” pointing to your folder “tutorials”

Click Browse and select your folder “tutorials”



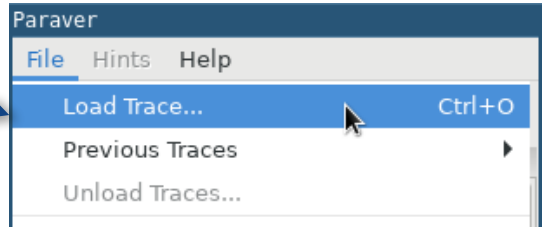
First steps of analysis

- Copy the trace to your laptop

```
laptop$ scp <USER>@jusuf.fz-juelich.de: \
tools-material/extrae/lulesh2.0_i_27p.* $HOME
```

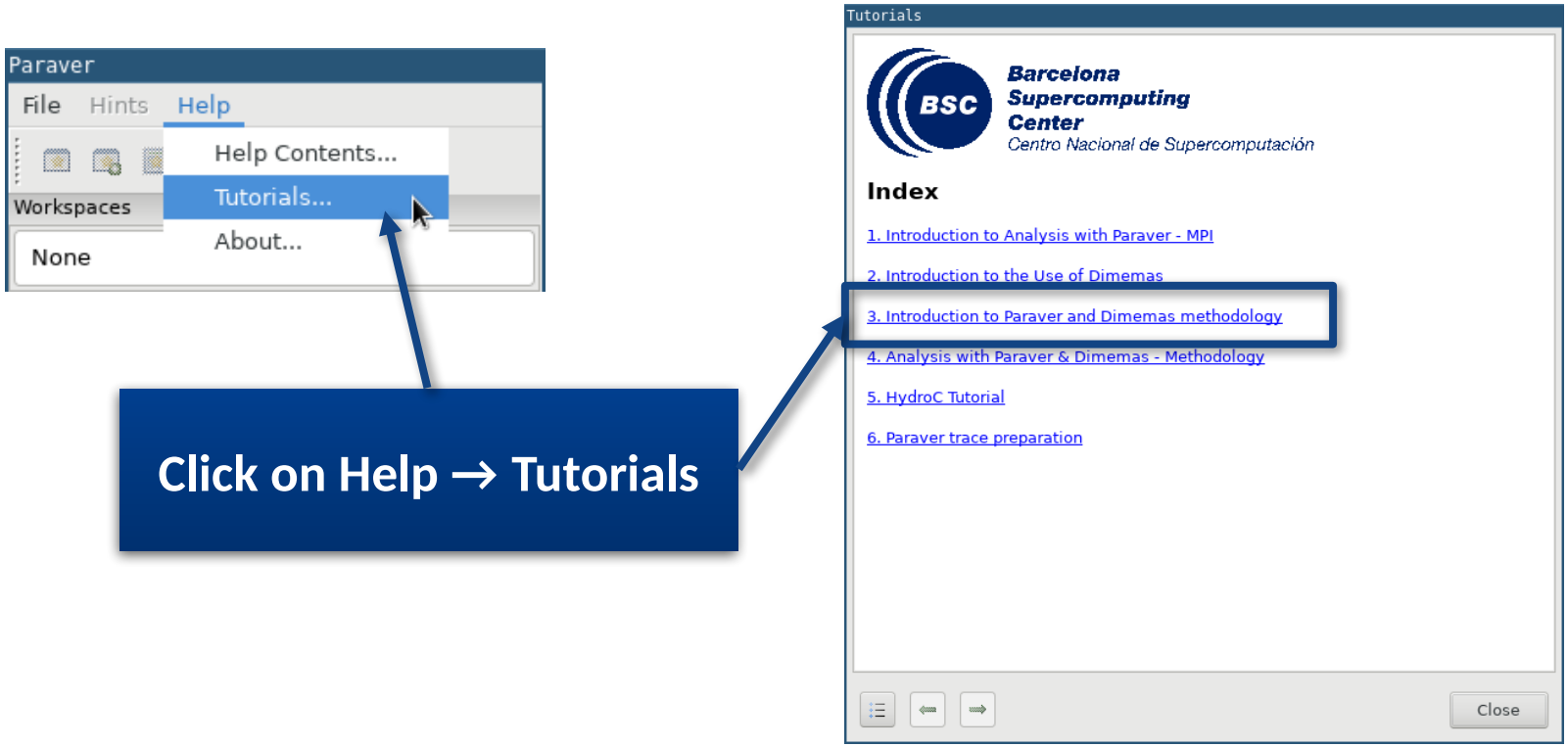
- Load the trace with Paraver

Click on File → Load Trace → Browse to "lulesh2.0_i_27p.prv"



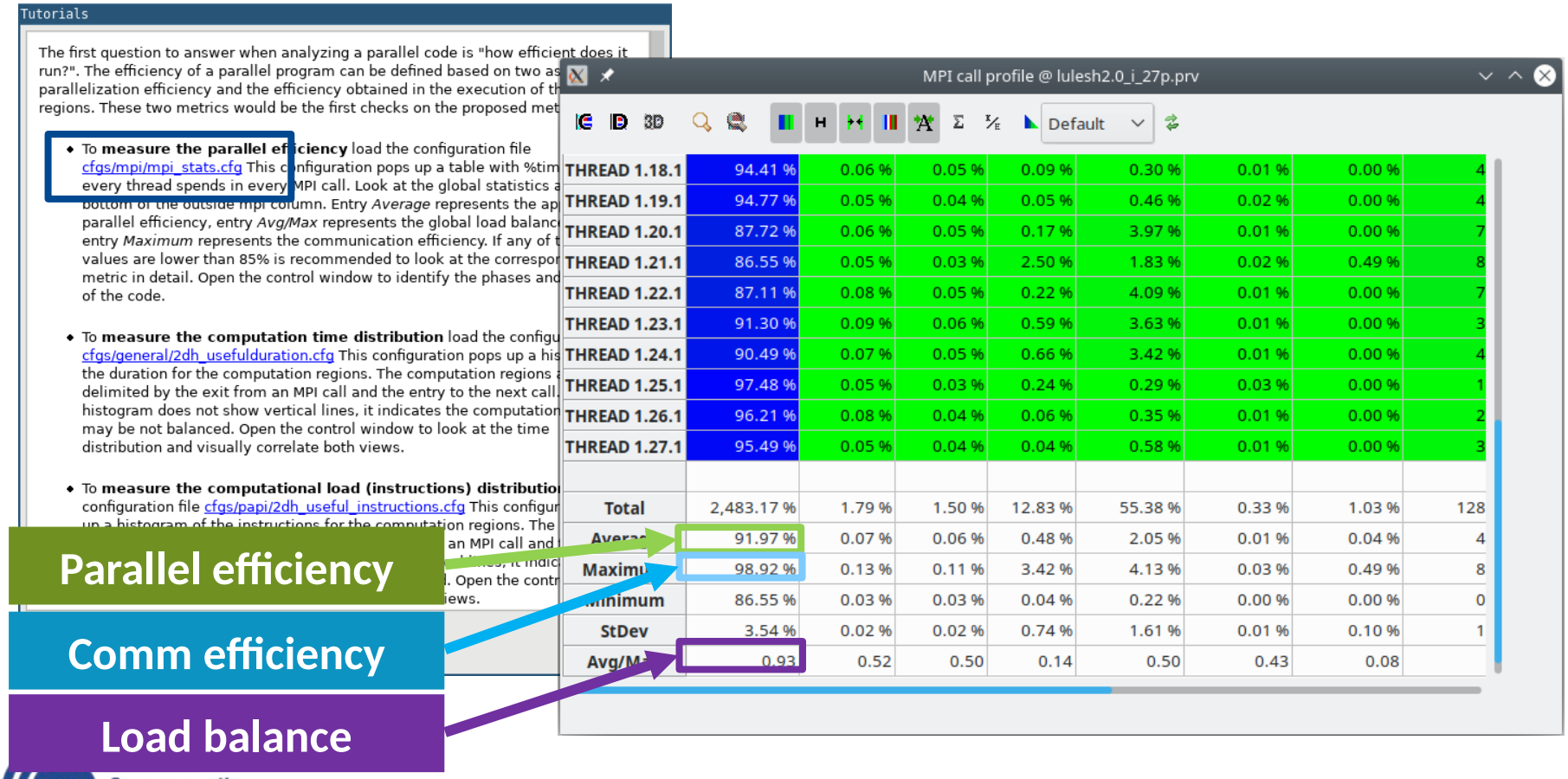
First steps of analysis

- Follow Tutorial #3
  - Introduction to Paraver and Dimemas methodology



Measure the parallel efficiency

- Click on “mpi_stats.cfg”
  - Check the **Average** for the column labeled “**Outside MPI**”



Focus on the iterative part

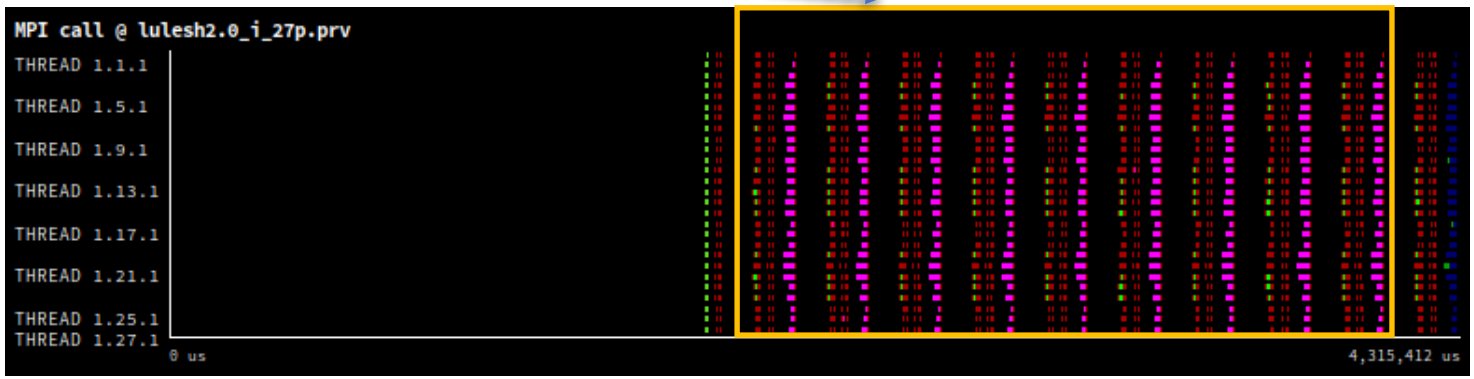
Click on "Open Control Window"

MPI call profile @ lulesh2.0_i_27p.prv

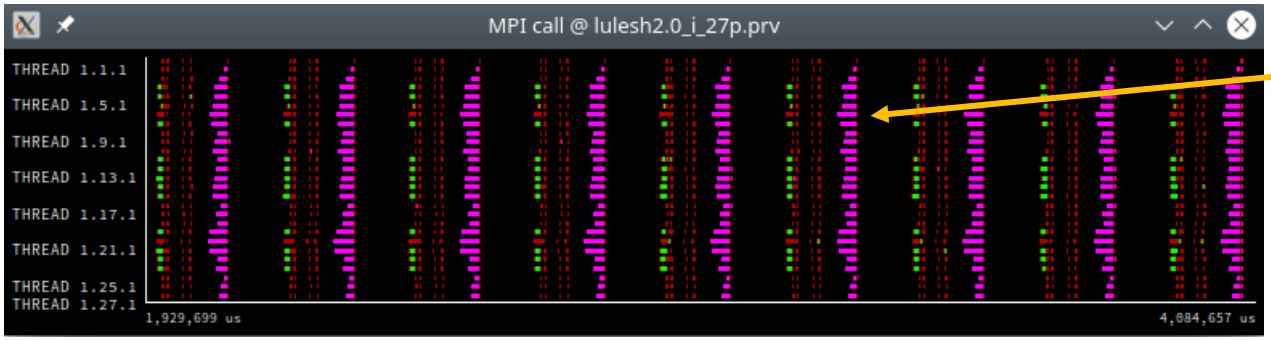
Default

THREAD 1.18.1	94.41 %	0.06 %	0.05 %	0.09 %	0.30 %	0.01 %	0.00 %	4
THREAD 1.19.1	94.77 %	0.05 %	0.04 %	0.05 %	0.46 %	0.02 %	0.00 %	4
THREAD 1.20.1	87.72 %	0.06 %	0.05 %	0.17 %	3.97 %	0.01 %	0.00 %	7
THREAD 1.21.1	86.55 %	0.05 %	0.03 %	2.50 %	1.83 %	0.02 %	0.49 %	8
THREAD 1.22.1	87.11 %	0.08 %	0.05 %	0.22 %	4.09 %	0.01 %	0.00 %	7
THREAD 1.23.1	91.30 %	0.09 %	0.06 %	0.59 %	3.63 %	0.01 %	0.00 %	3
THREAD 1.24.1	90.49 %	0.07 %	0.05 %	0.66 %	3.42 %	0.01 %	0.00 %	4
THREAD 1.25.1	97.48 %	0.05 %	0.03 %	0.24 %	0.29 %	0.03 %	0.00 %	1
THREAD 1.26.1	96.21 %	0.08 %	0.04 %	0.06 %	0.35 %	0.01 %	0.00 %	2
THREAD 1.27.1	95.49 %	0.05 %	0.04 %	0.04 %	0.58 %	0.01 %	0.00 %	3
Total	2,483.17 %	1.79 %	1.50 %	12.83 %	55.38 %	0.33 %	1.03 %	128
Average	91.97 %	0.07 %	0.06 %	0.48 %	2.05 %	0.01 %	0.04 %	4
Maximum	98.92 %	0.13 %	0.11 %	3.42 %	4.13 %	0.03 %	0.49 %	8
Minimum	86.55 %	0.03 %	0.03 %	0.04 %	0.22 %	0.00 %	0.00 %	0
StDev	3.54 %	0.02 %	0.02 %	0.74 %	1.61 %	0.01 %	0.10 %	1
Avg/Max	0.93	0.52	0.50	0.14	0.50	0.43	0.08	

Zoom iterative part



Recalculate efficiency of iterative region



Right click -> Copy

Right click -> Paste -> Time

MPI call profile @ lulesh2.0_i_27p.prv

Default

THREAD 1.20.1	78.31 %	0.10 %	0.08 %	0.26 %	6.91 %	14.27 %	0.08 %
THREAD 1.21.1	76.25 %	0.08 %	0.05 %	4.53 %	2.94 %	16.04 %	0.10 %
THREAD 1.22.1	77.21 %	0.12 %	0.08 %	0.39 %	7.09 %	15.00 %	0.10 %
THREAD 1.23.1	84.78 %	0.15 %	0.10 %	1.08 %	6.19 %	7.62 %	0.07 %
THREAD 1.24.1	83.36 %	0.11 %	0.08 %	1.14 %	5.87 %	9.36 %	0.08 %
THREAD 1.25.1	95.64 %	0.08 %	0.05 %	0.41 %	0.49 %	3.26 %	0.08 %
THREAD 1.26.1	93.31 %	0.12 %	0.07 %	0.11 %	0.59 %	5.72 %	0.07 %
THREAD 1.27.1	92.10 %	0.08 %	0.06 %	0.07 %	0.91 %	6.71 %	0.07 %
Total	2,318.40 %	2.68 %	2.48 %	22.79 %	94.91 %	256.50 %	2.25 %
Average	85.87 %	0.10 %	0.09 %	0.84 %	3.52 %	9.50 %	0.08 %
Maximum	98.23 %	0.19 %	0.19 %	6.12 %	7.16 %	16.04 %	0.11 %
Minimum	76.25 %	0.05 %	0.05 %	0.07 %	0.38 %	0.02 %	0.06 %
StDev	6.25 %	0.03 %	0.03 %	1.33 %	2.80 %	3.83 %	0.01 %
Avg/Max	0.87	0.52	0.49	0.14	0.49	0.59	0.74

Parallel efficiency

Comm efficiency

Load balance

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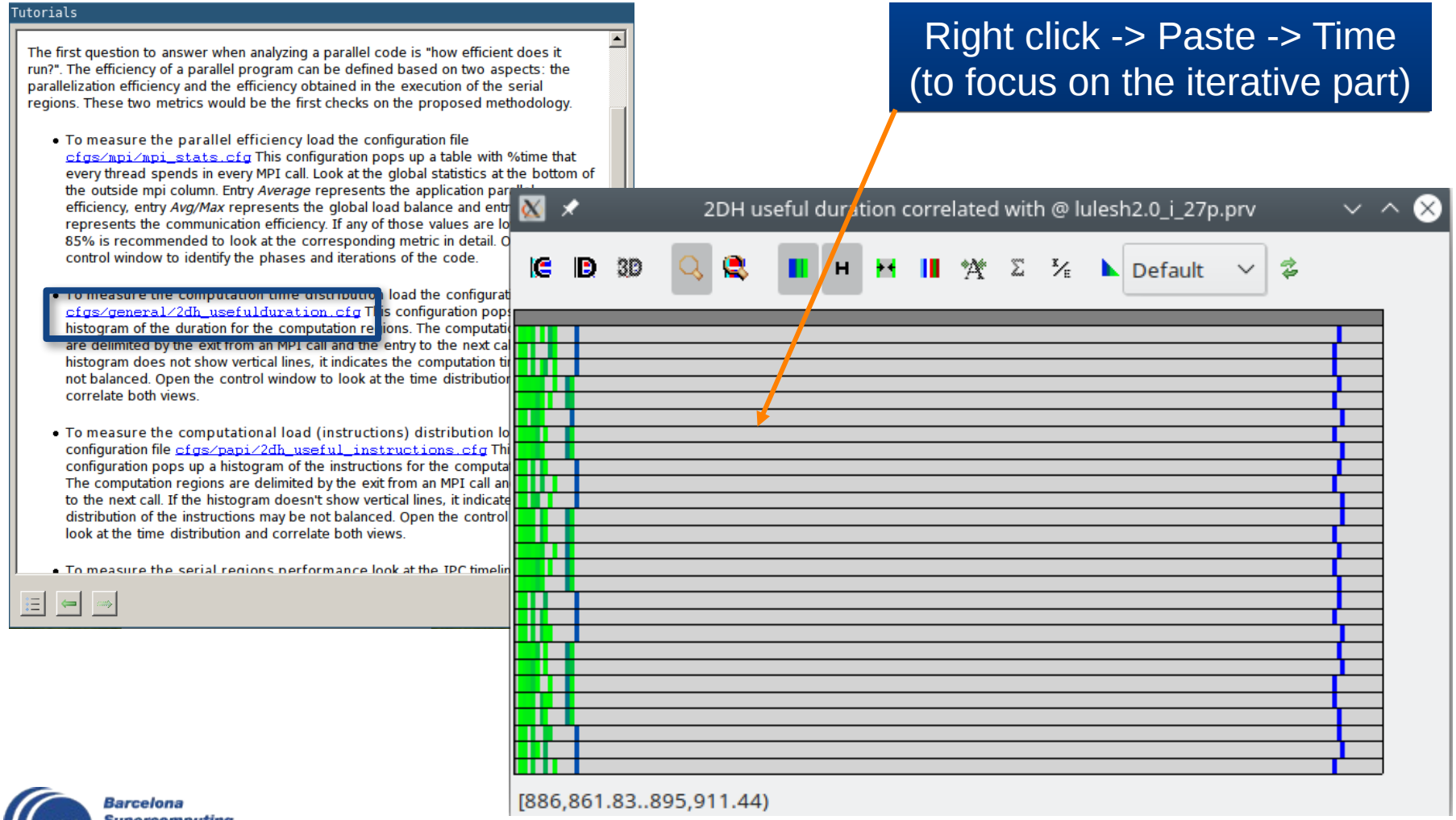
Computation time distribution

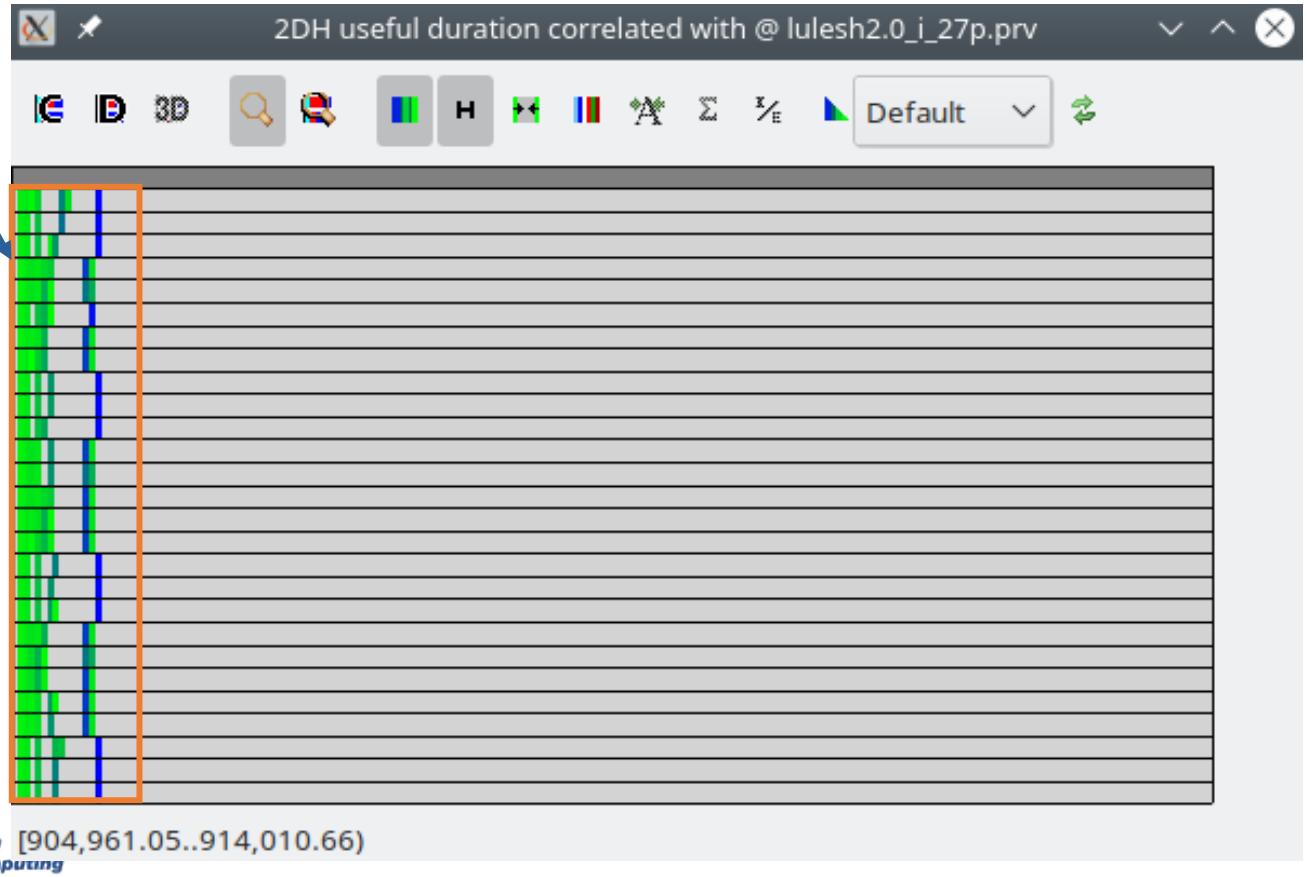
- Click on “2dh_usefulduration.cfg” (2nd link) Shows **time computing**



Computation time distribution

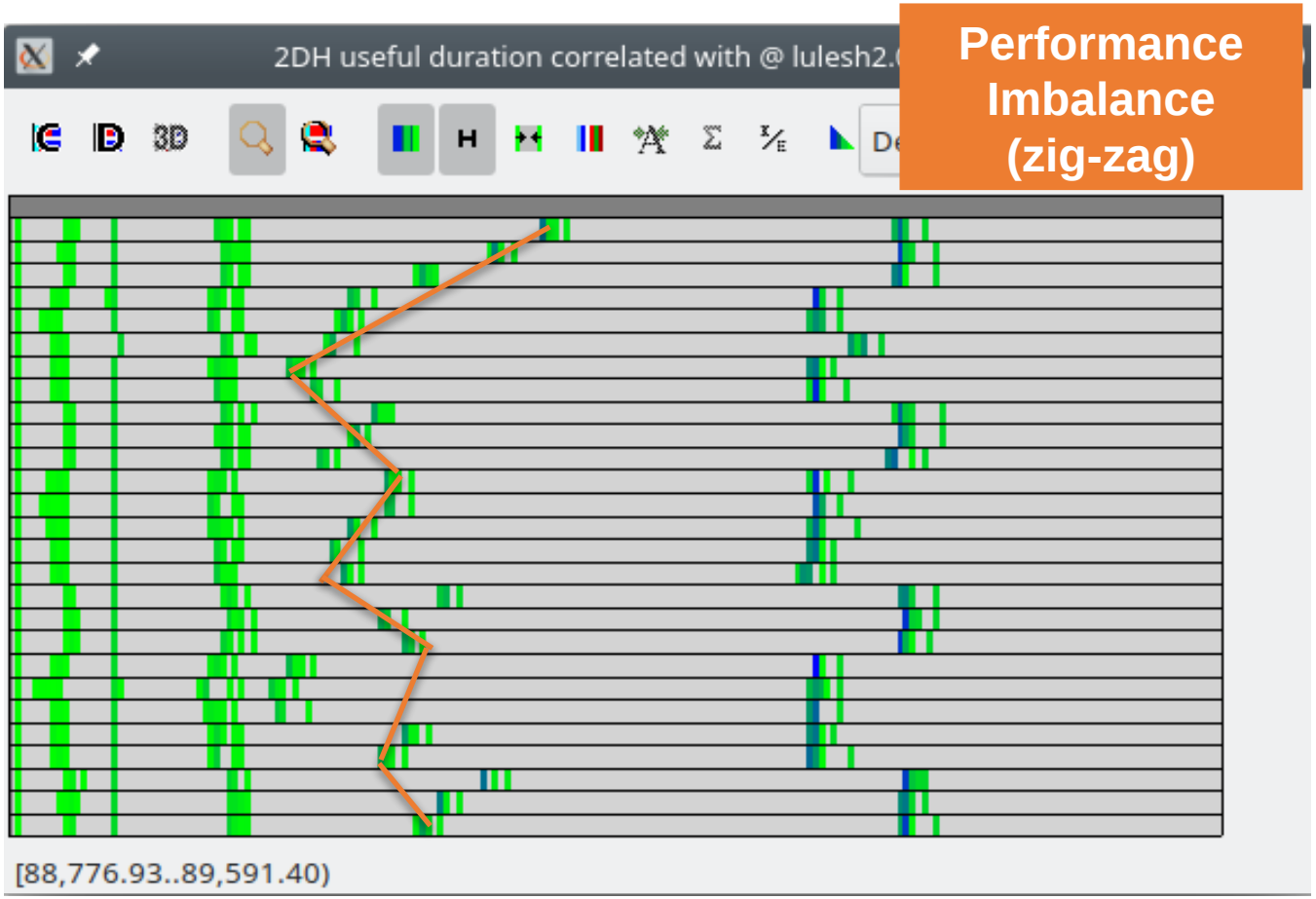
- Click on “2dh_usefulduration.cfg” (2nd link) Shows **time computing**

Zoom in



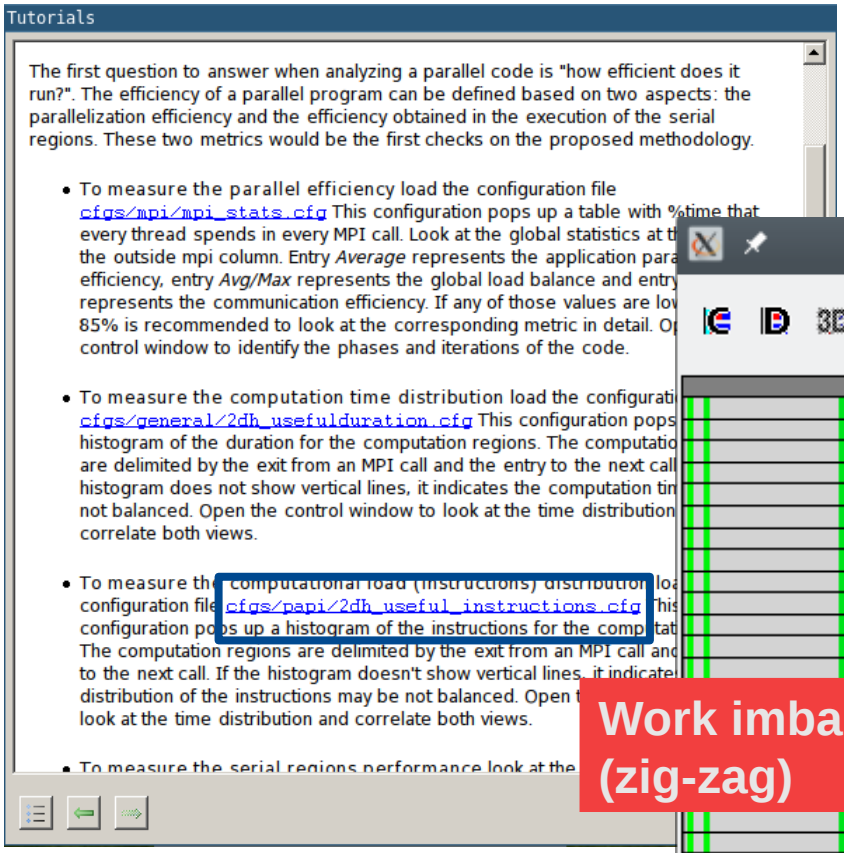
Computation time distribution

- Click on “2dh_usefulduration.cfg” (2nd link) Shows **time computing**

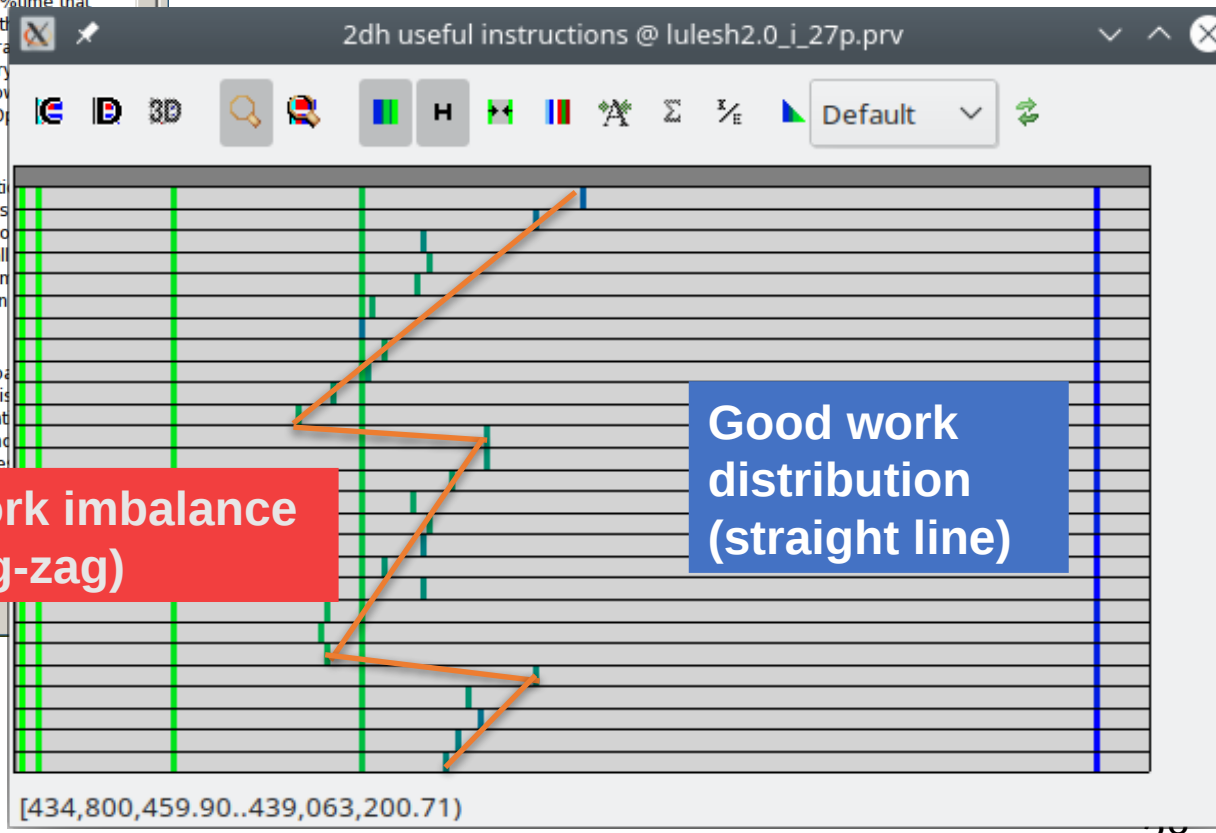


Computation load distribution

- Click on “2dh_useful_instructions.cfg” (3rd link) Shows **amount of work**



Focus only on the iteration part (copy time and zoom done)



Work imbalance (zig-zag)

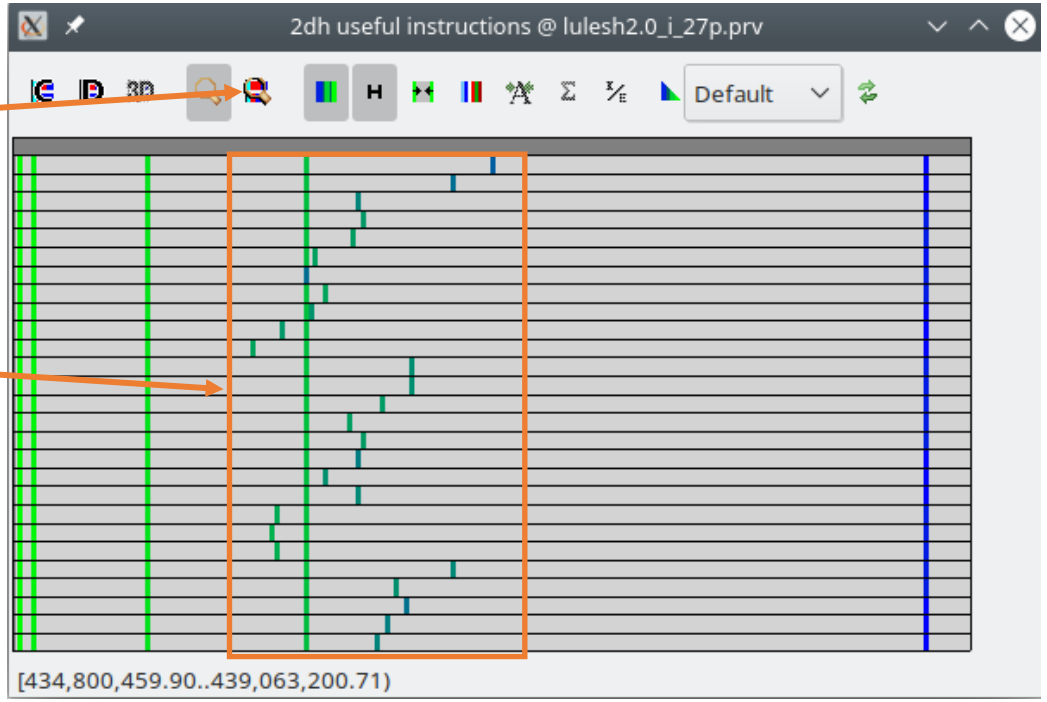
Good work distribution (straight line)

Where does this happen?

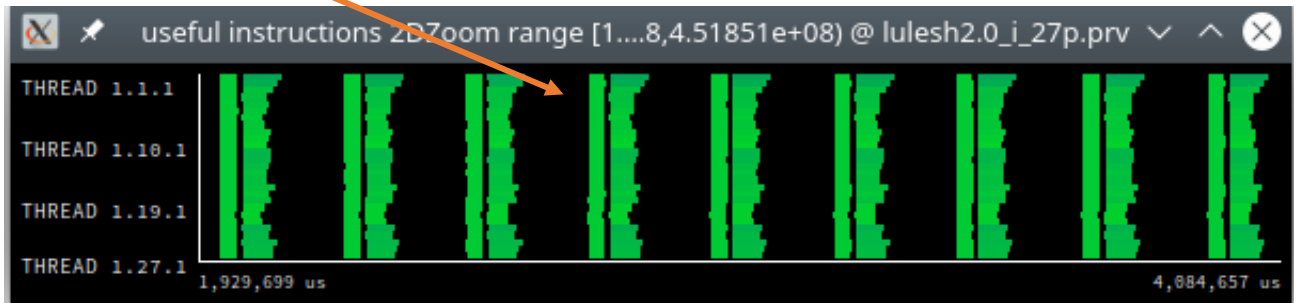
- Go from the table to the timeline

1. Click on "Open Filtered Control Window"

2. Select this area (by drag-and-dropping)



Right click
→ Fit Semantic Scale
→ Fit both



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Right click
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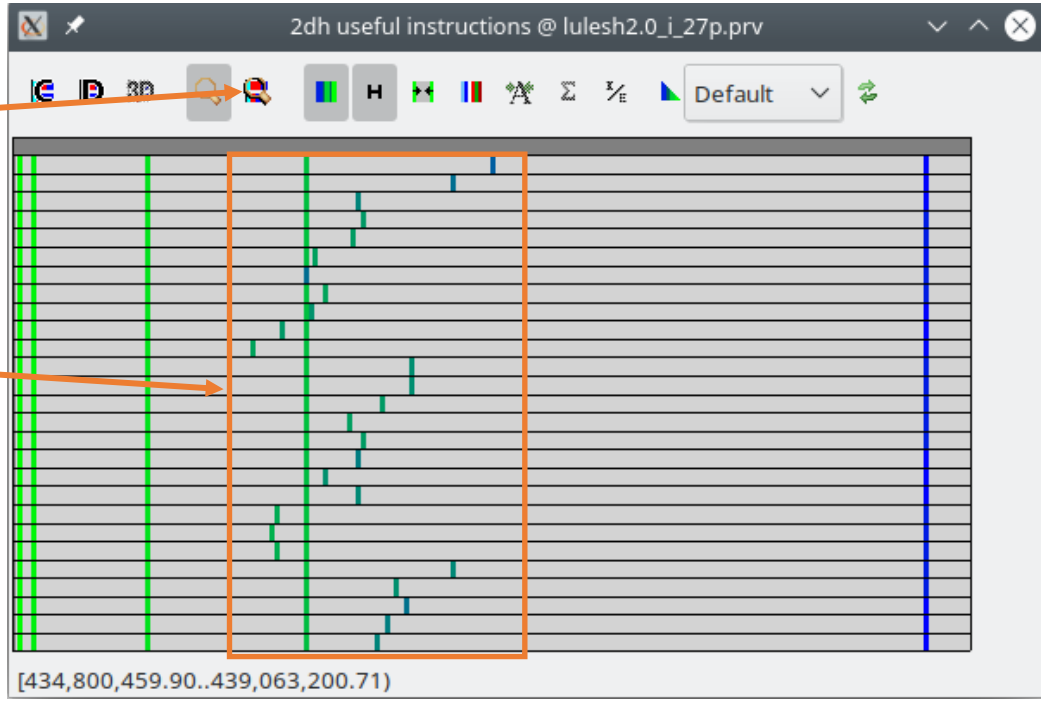
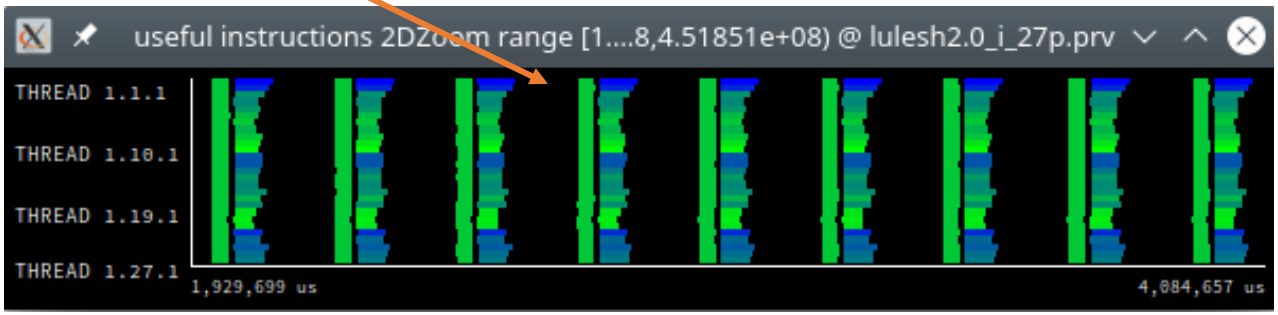
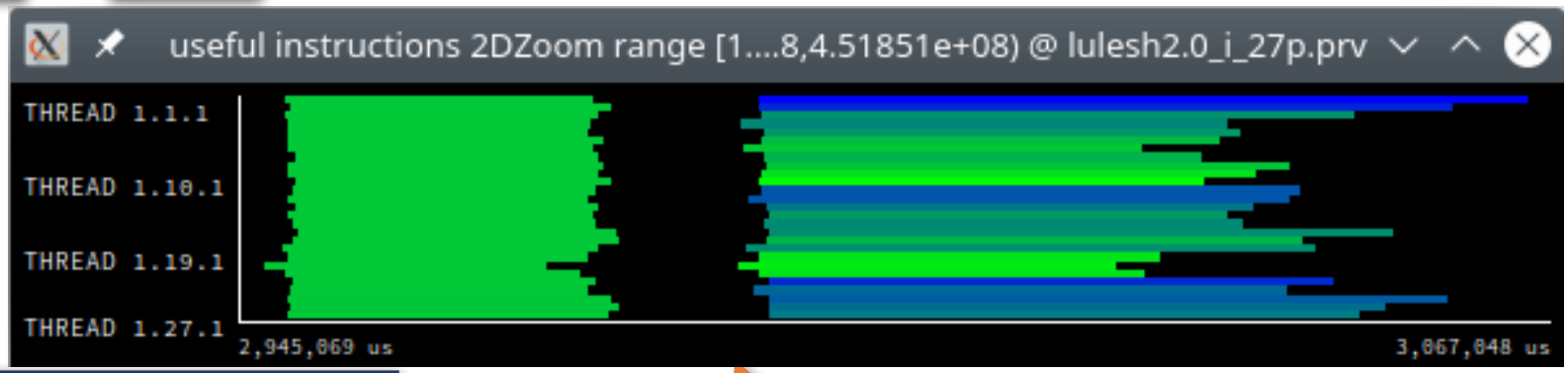


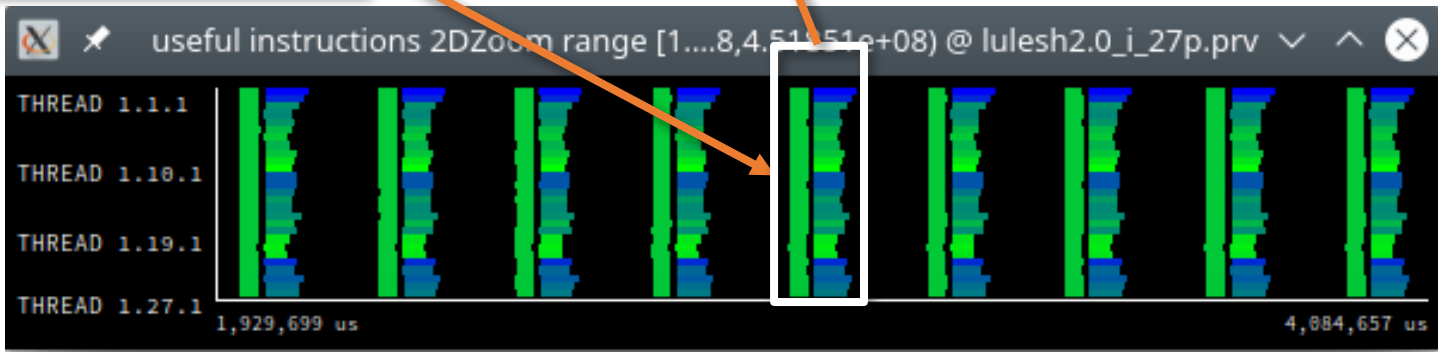


Where does this happen?

- **Slow** & **Fast** at the same time? ⇒ Imbalance

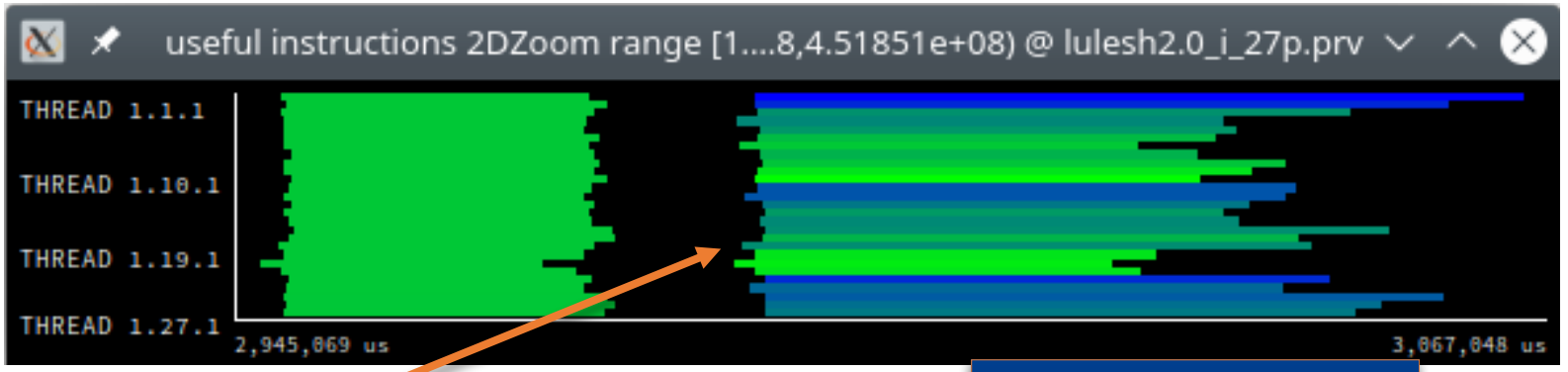


Zoom into
1 of the iterations
(by drag-and-dropping)



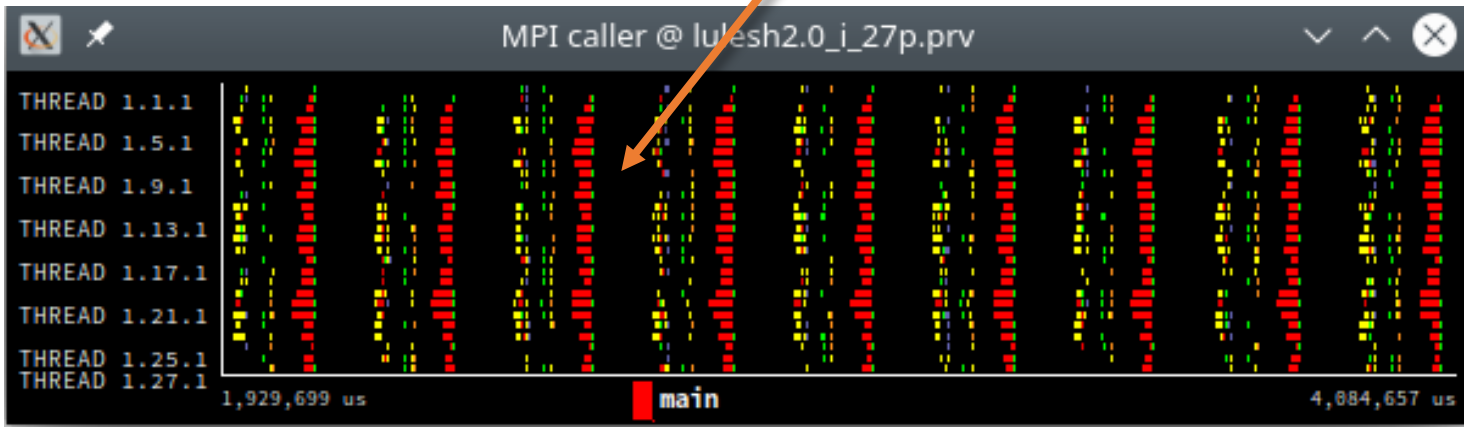
Where does this happen?

- Hints → Call stack references → Caller function



Right click → Copy

Right click → Paste → Time



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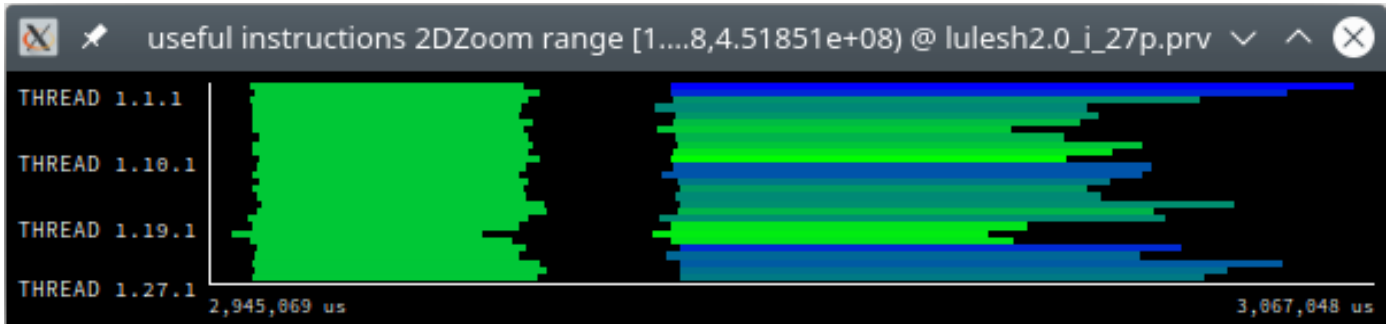
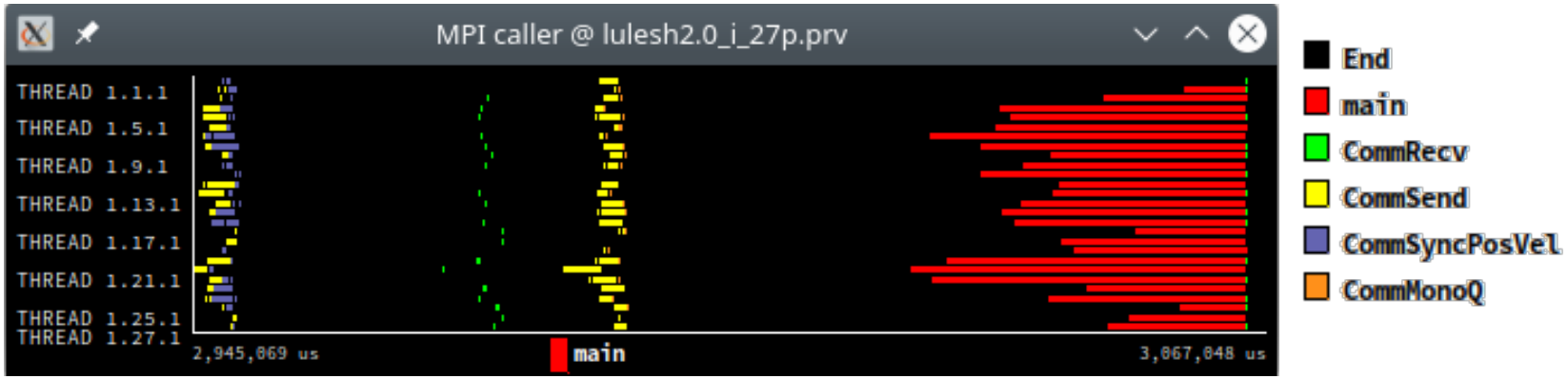
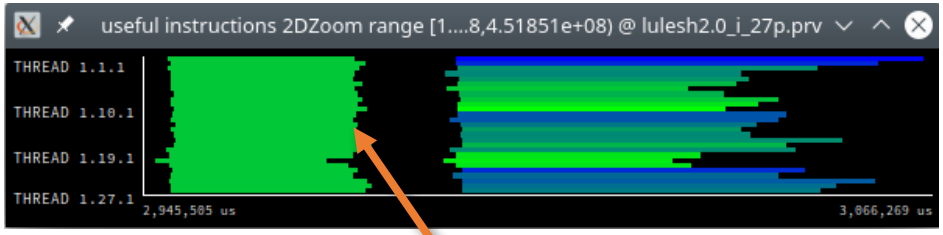
- Hints → Call stack references → Caller function

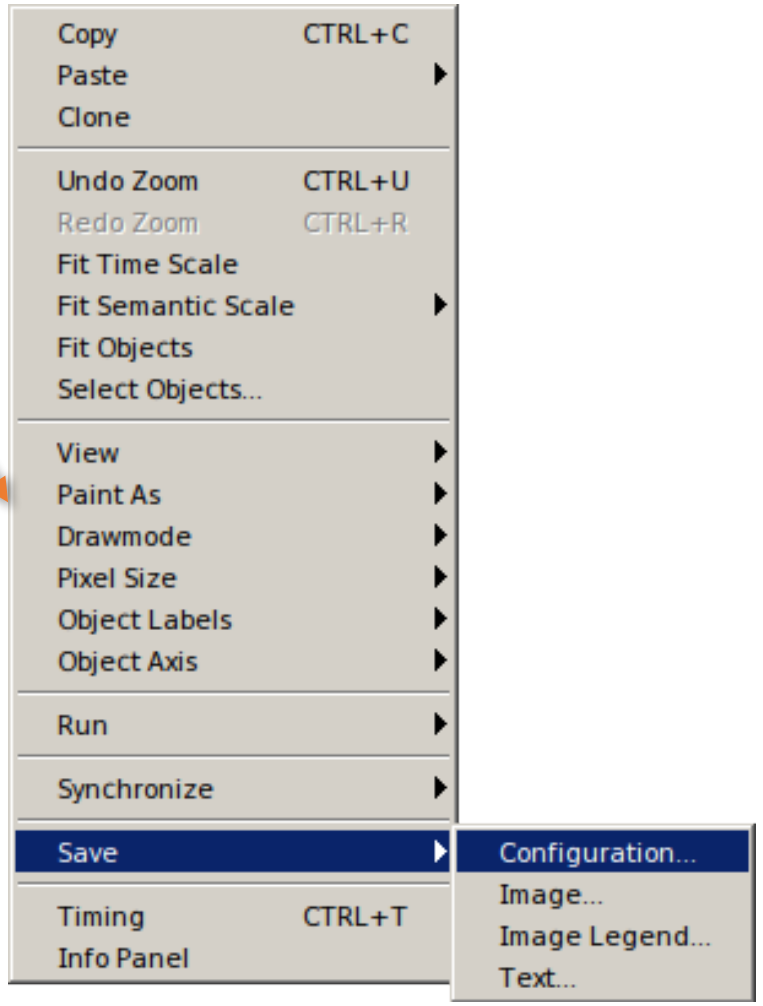




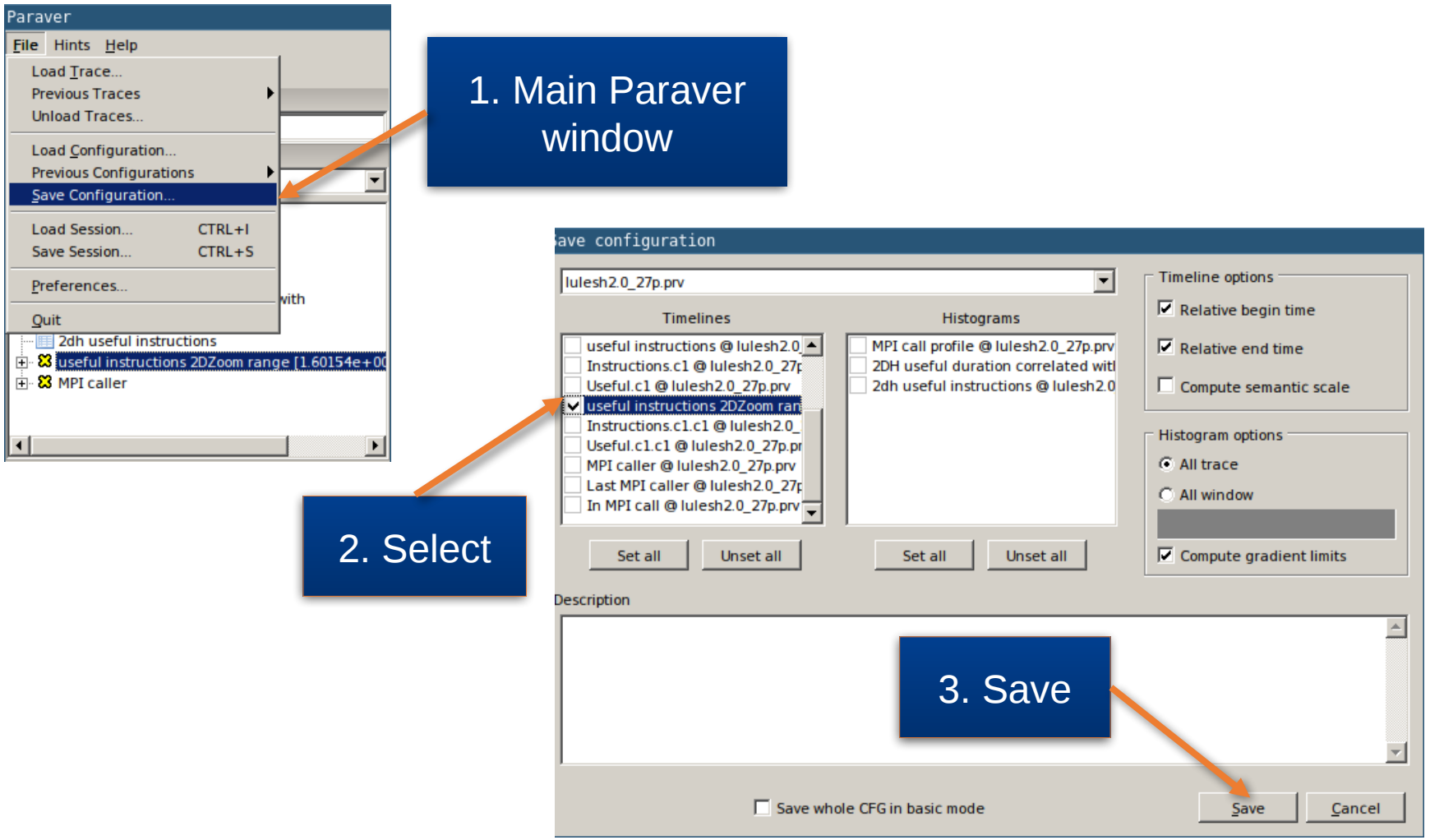
Save CFG's (2 methods)



Right click on timeline

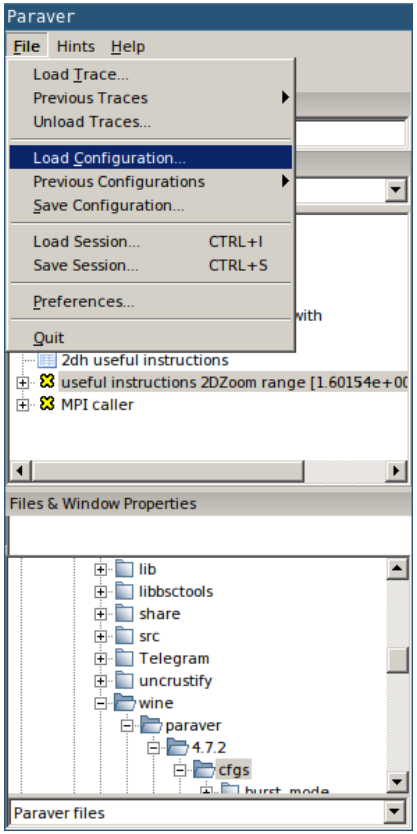


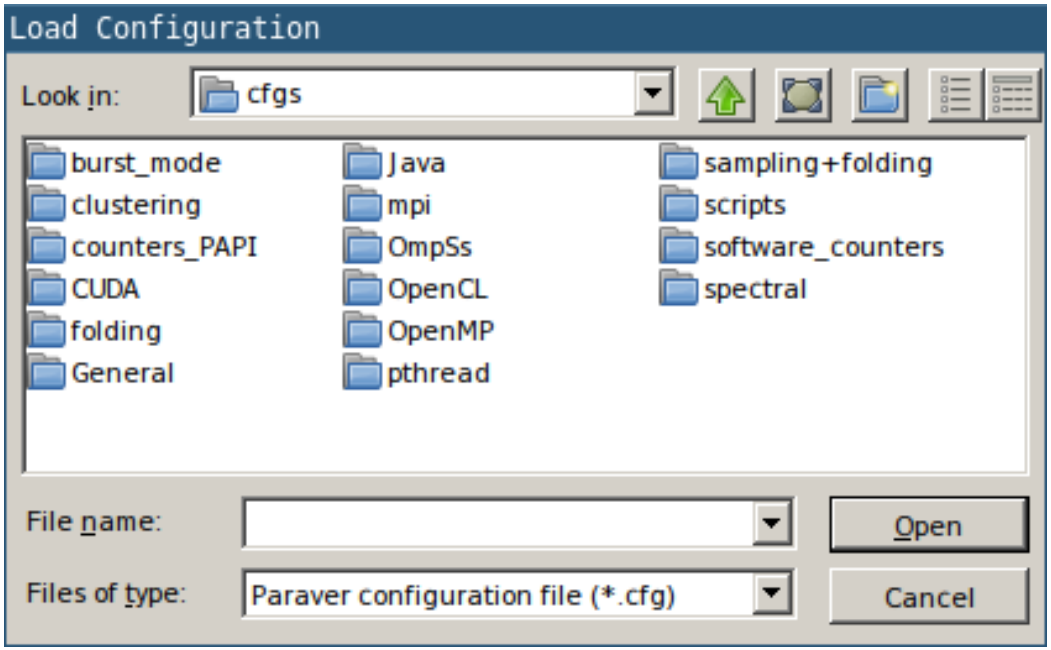
Save CFG's (2 methods)



CFG's distribution

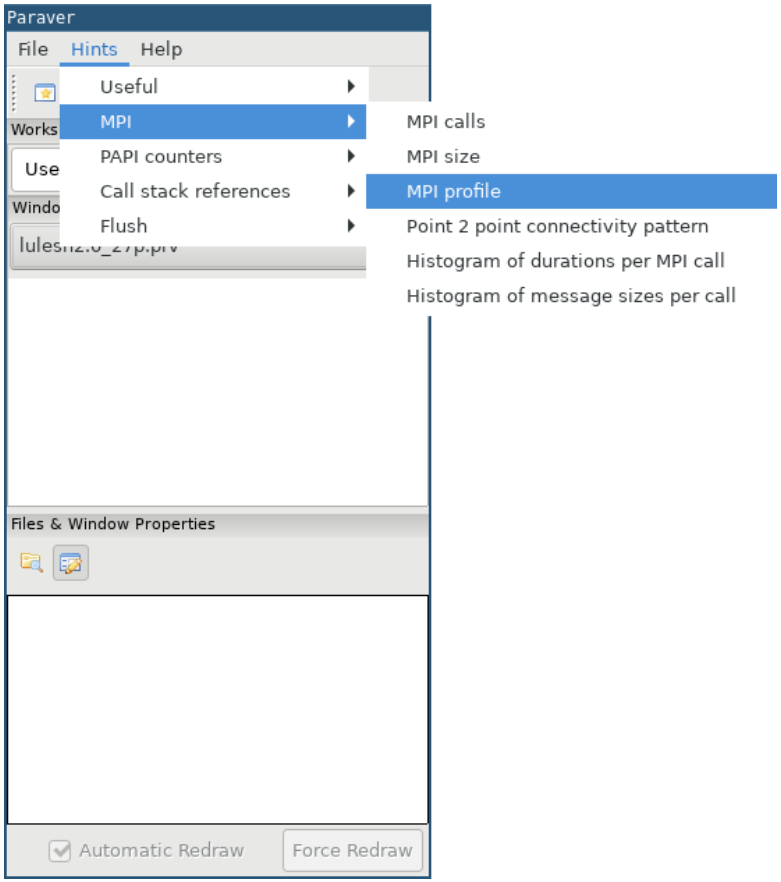
- Paraver comes with many more included CFG's





Hints: a good place to start!

- Paraver suggests CFG's based on the contents of the trace



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Takeaway: Analyse efficiencies and unbalances

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19/04/2021

POP Performance Analysis

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Clustering Hands-On

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Cluster-based analysis (I)

- Run the clustering tool on the trace you generated

```
jusuf$ source /p/project/training2214/setup.sh

jusuf$ cd $HOME/tools-material/clustering

jusuf$ BurstClustering \
-d cluster.xml \
-i ../extrae/lulesh2.0_i_27p.prv \
-o lulesh2.0_i_27p-clustered.prv
```

- If you didn't get your own trace, use a prepared one from:

```
jusuf$ ls
$HOME/tools-material/traces/lulesh2.0_i_27p.prv
```

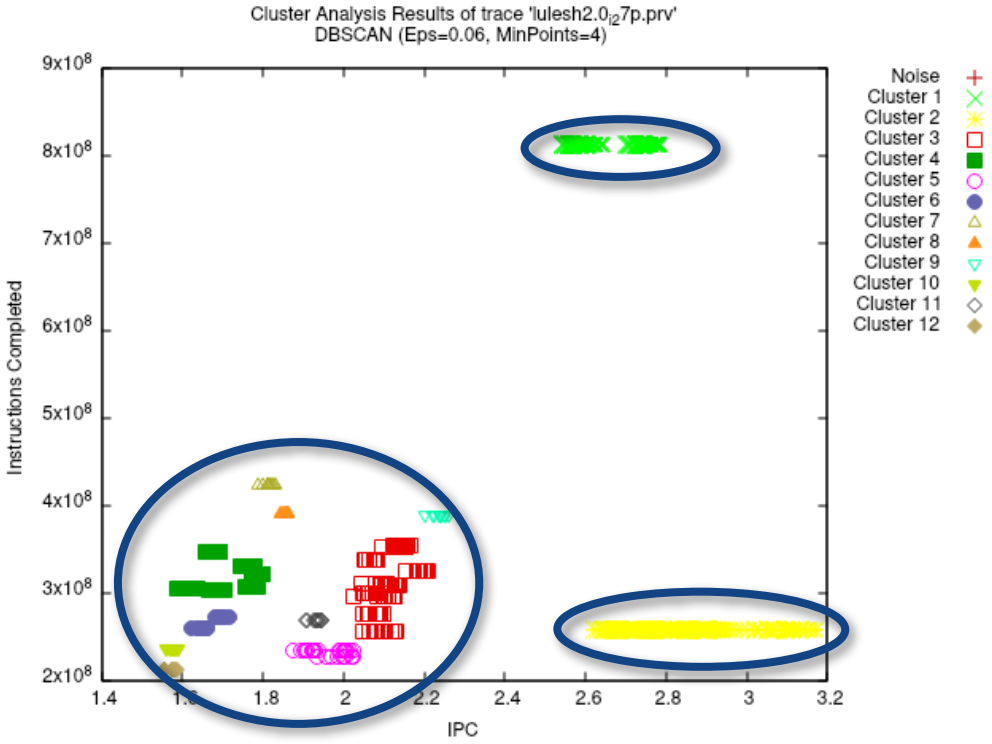
Cluster-based analysis (II)

- Check the clustering scatter plot

```
jusuf$ gnuplot \
lulesh2.0_i_27p-clustered.IPC.PAPI_TOT_INS.gnuplot
```

- Identify main computing trends
- Work (Y) vs. Performance (X)
- Look at the clusters shape
  - Variability in both axes

  indicate **potential imbalances**



Cluster-based analysis (III)

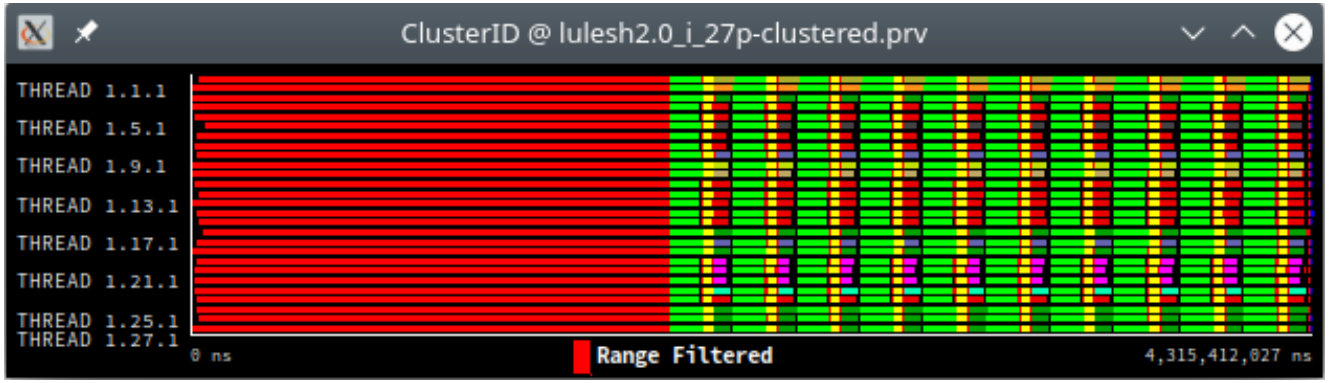
- Check the clustered trace
  - Copy the trace to your laptop

```
jusuf$ scp <USER>@jusuf.fz-juelich.de: \
tools-material/clustering/*.{pcf,prv,row} $HOME
```

  - Load with Paraver

```
laptop$ paraver/bin/wxparaver \
$HOME/lulesh2.0_i_27p_clustered.prv
```

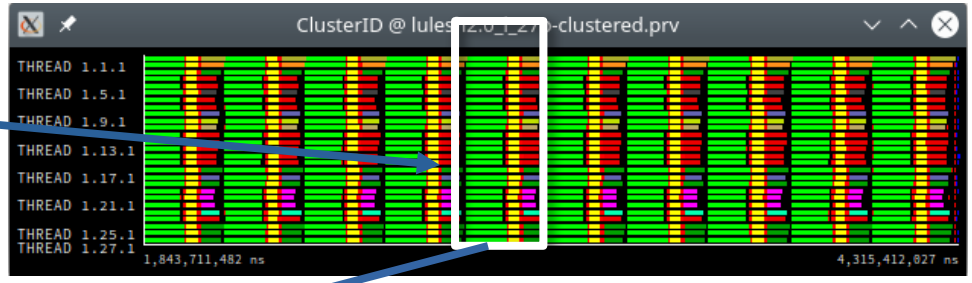
  - Display the distribution of clusters over time
    - File Load configuration paraver/cfgs/clustering/clusterID_window.cfg

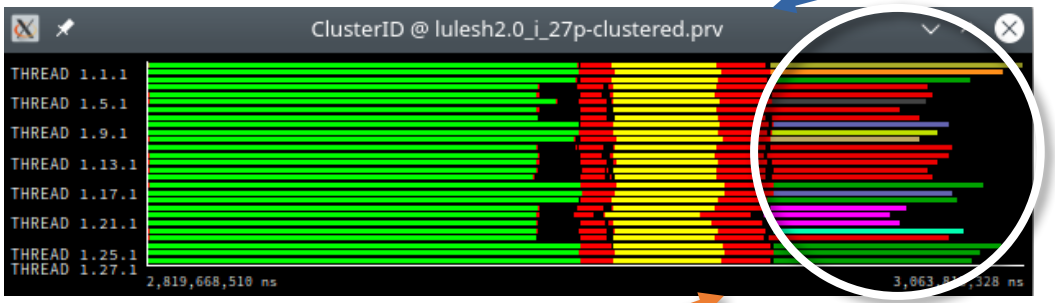


Cluster-based analysis (III)

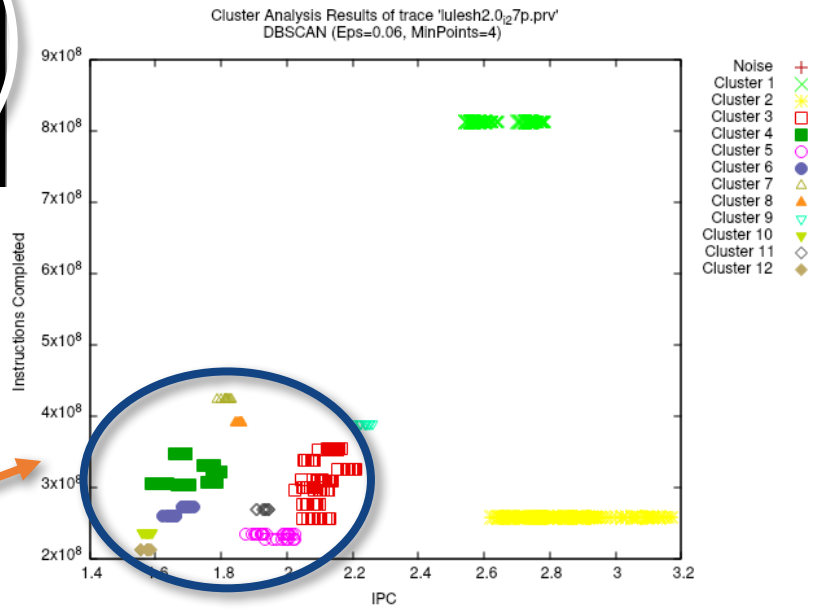
- Correlate scatter plots & timelines to detect imbalances

Zoom into
1 of the iterations
(by drag-and-dropping)





Variable work
and/or
Variable speed
+
Simultaneously @ different processes
=
Imbalances



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End Clustering Hands-On

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