Post-processing

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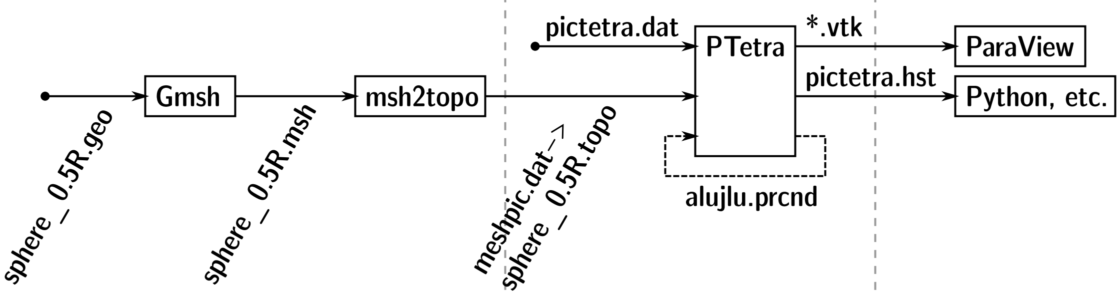
03.02.22

Approaching the end

Step 1:
Mesh generation
(25.01.22)

Step 2:
Simulation
(27.01.22)

Step 3:
Post-processing
(03.02.22)



Outline

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Visualizing fields with ParaView

PTetra VTK files:

- Volumetric fields: pictetra⟨*timestep*⟩.vtk
- Surface fields: scc⟨*timestep*⟩.vtk

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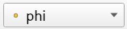
Available fields: 

- Potential: phi, phiAv (averaged)
- Charge density: rho, rhoAv (averaged)
- Number density: dne, dni
- Surface current density: J
- Force per surface area: Fx, Fy, Fz

(everything in SI units)

Visualizing fields with ParaView

Example of ParaView use:

- Open and combine data 

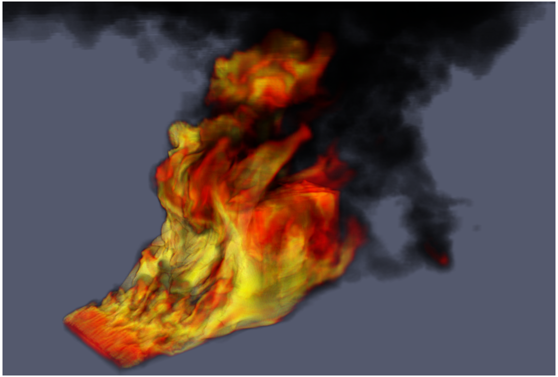
- Contour, clip, slice 
- Animate (open entire group) 
- Plot over line 
- Adjust colorbar 
- Preset orientations 

See the ParaView tutorial: `https://www.paraview.org/tutorials`

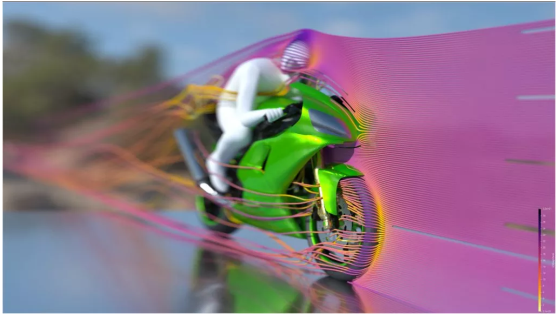
Example ParaView Visualizations

Figure: PUNC++ simulation (`punc.rtfd.io`)

Example ParaView Visualizations



(Sandia National Labortory)



(NVIDIA)

See more at `https://www.paraview.org/gallery`

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Noise and averaging

Main disadvantage of PIC:

Particle noise prop. to $\sqrt{N}$ (N is number of sim. particles)
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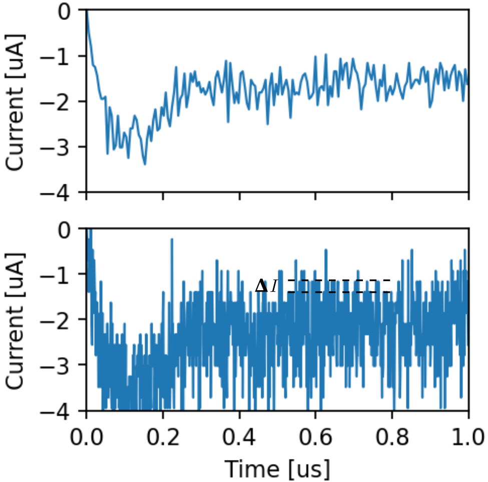

Noise and averaging

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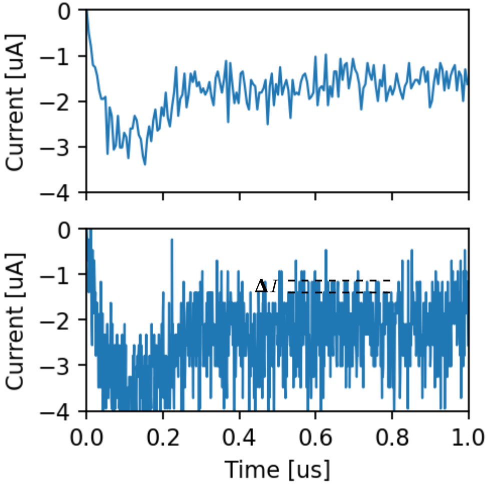
Currents are not only noisy, but discrete:

- In nature: sum of δ-pulses
- In simulations: granularity $\Delta I = q/\Delta t$ (q is charge of sim. particle)



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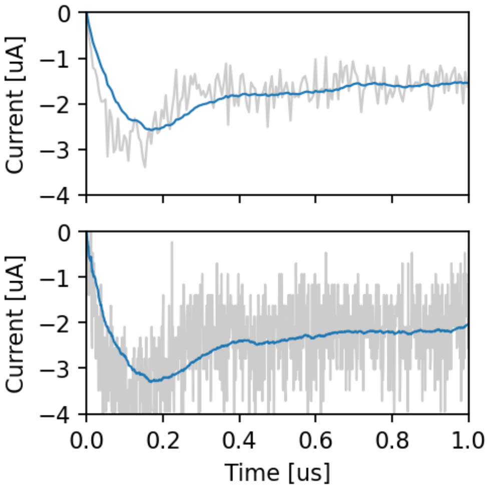
Simulations are identical except for Δt.
Lower is more accurate. Use averaging!



Noise and averaging

Exponential moving average of time-series $\{x^0, x^1, ...\}$:

$$\bar{x}^0 = x^0$$
$$\bar{x}^n = \alpha x^n + (1-\alpha)\bar{x}^{n-1}$$

$\alpha = 1 - e^{-\frac{\Delta t}{\tau}}$ and τ is the relaxation time.
Adjusting weight imbalance:

$$\tilde{x}^n = \frac{\bar{x}^n}{W^n}$$
$$W^n = \alpha + (1-\alpha)W^{n-1}$$

Memory efficent, also works on field quantities.

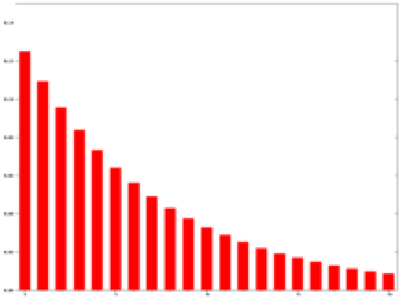


Figure: Weights of past samples.
(From Wikipedia)

Outline

Inspecting time series

Time series stored in pictetra.hst:

```
#nepop= 1nipop= 1  sc_nstruc= 2
# timestep      time            netot          nitot          Te_eff         pot1           sc_phi         sc_q           sc_i
        0      0.000000E+00        5000000        5000000    1.099091E-01   3.798997E-17   3.000000E+00   0.000000E+00   0.000000E+00   3.00
        1      1.210681E-09        5000148        4999826    1.099306E-01  -2.702192E-16   3.000000E+00  -1.620472E-16  -1.338480E-07   3.00
        2      2.421362E-09        4999988        4999765    1.099913E-01  -6.032211E-16   3.000000E+00  -5.772932E-16  -3.429855E-07   3.00
        3      3.632043E-09        4999917        4999691    1.100872E-01  -9.380563E-16   3.000000E+00  -1.301442E-15  -5.981333E-07   3.00
      ...         ...                ...            ...            ...            ...            ...            ...            ...

                                Number of      Number of      Estimate of    Estimate of     Spacecraft     Spacecraft     Spacecraft
                                electrons      ions           el. temp.      pot. energy     potential      charge         current
                                                                                            |                                            |
                                                                                            '--------------------------------------------'
                                                                                              Repeatead for each spacecraft component
```

Can be plotted with attached script:

```
$ ./plot.py Sphere_0.5R_3V_3V sc_i_0
$ ./plot.py -h
```

Outline

Introduction to Langmuir

Programmatic access to $I(V)$, also in cases where there are no analytic expressions.

Example:

```
# Typical F-layer plasma
plasma = [Electron(n=1e11, T=1000),
          Oxygen(n=1e11, T=1000)]

geometry = Cylinder(r=0.2*debye(plasma), l=10*debye(plasma))

V = np.linspace(-2, 2, 100)

I_OML = OML_current(geometry, plasma, V)
I_FL = finite_length_current(geometry, plasma, V)
```

See also https://langmuir.readthedocs.io

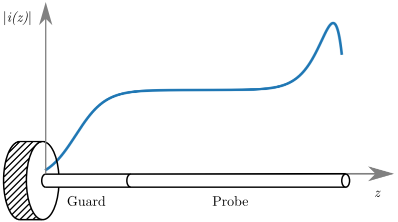


Figure: Current collected per unit length of a cylindrical probe Marholm and Marchand, DOI: 10.1103/PhysRevResearch.2.023016

Outline

Colors – Perceptual uniformity and order

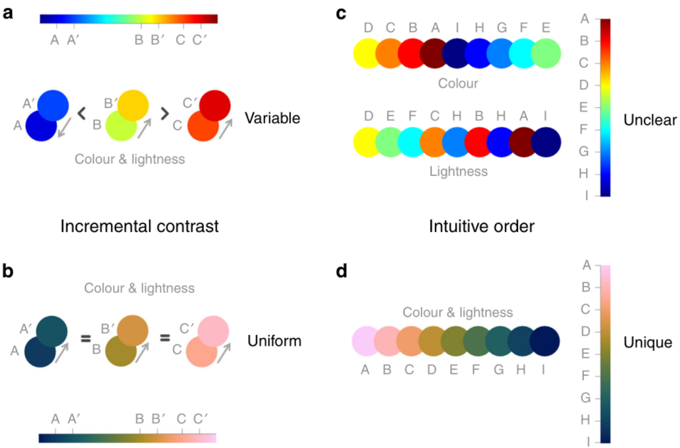


Figure: Crameri *et al.*, DOI: 10.1038/s41467-020-19160-7

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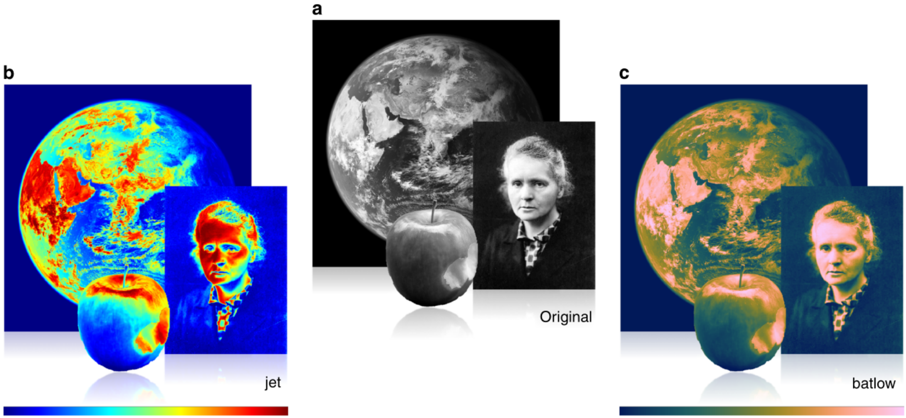

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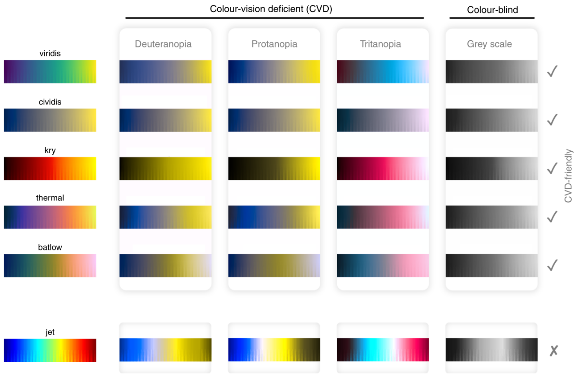
Colors – Color vision deficiency friendly



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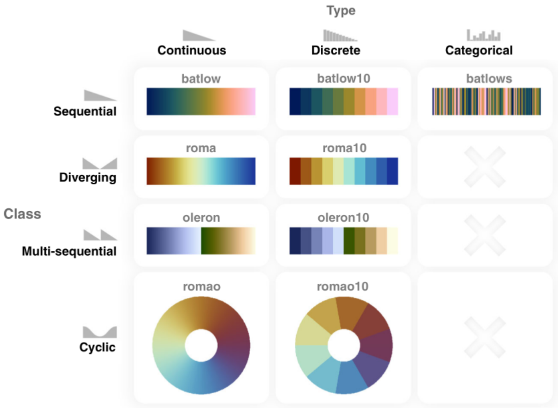
8% of men and 0.5% of women are red-green color blind (deuteranopia)

Colors – Color map classes



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