Fluid Beamer

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Thursday, 30 August 2012

Jos Stam's Stable Fluids

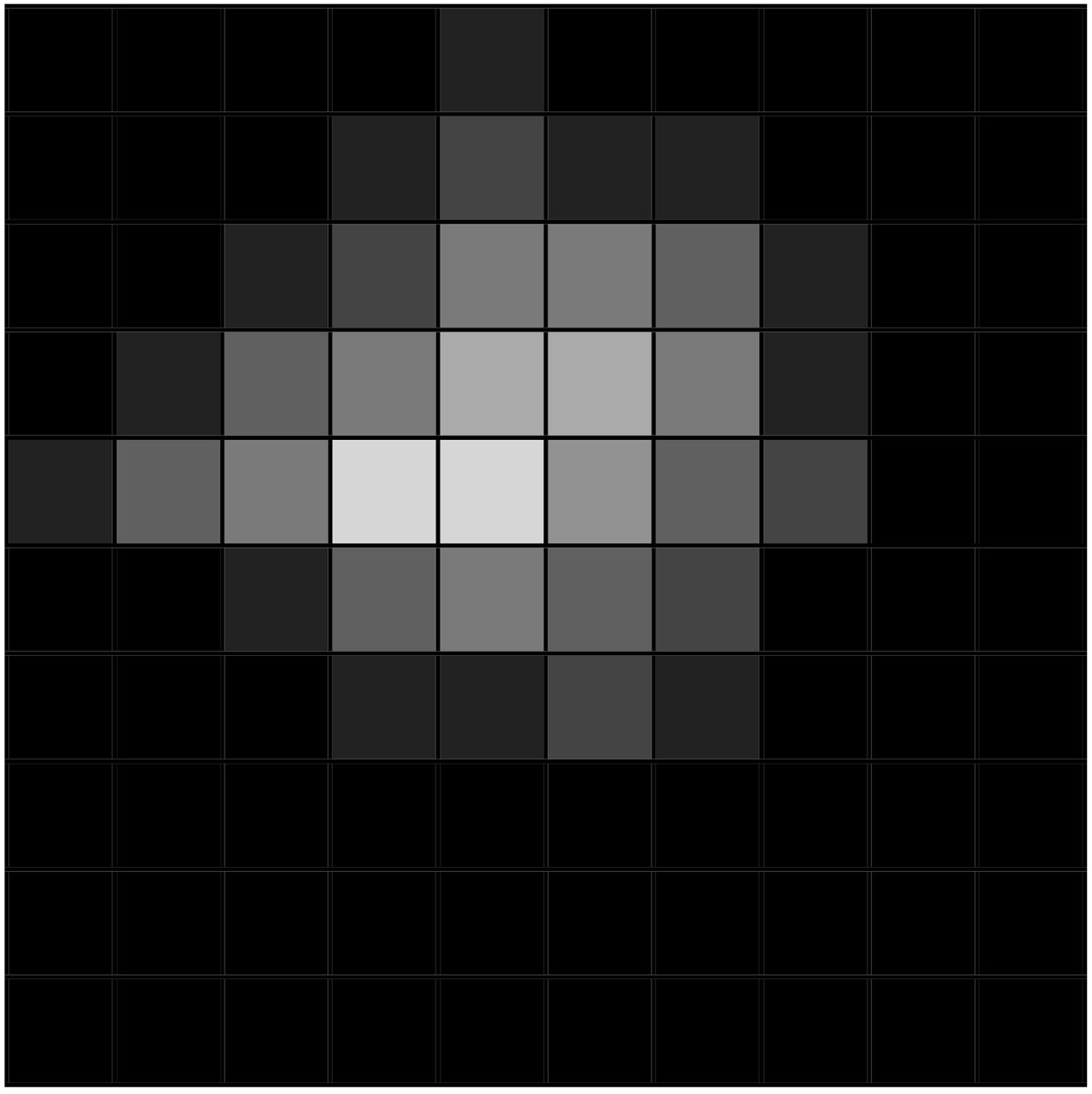
- Fast, real-time fluid flow simulation algorithm.

- Intended for games and animations,
  instead of accurate engineering simulation.

- Stable at arbitrary time steps.

```
demo: ./Main -scale 3 -size 200 200 -visc 0 -diff 0 +RTS -N2 -qa -qg
```

“Smoke in a box”

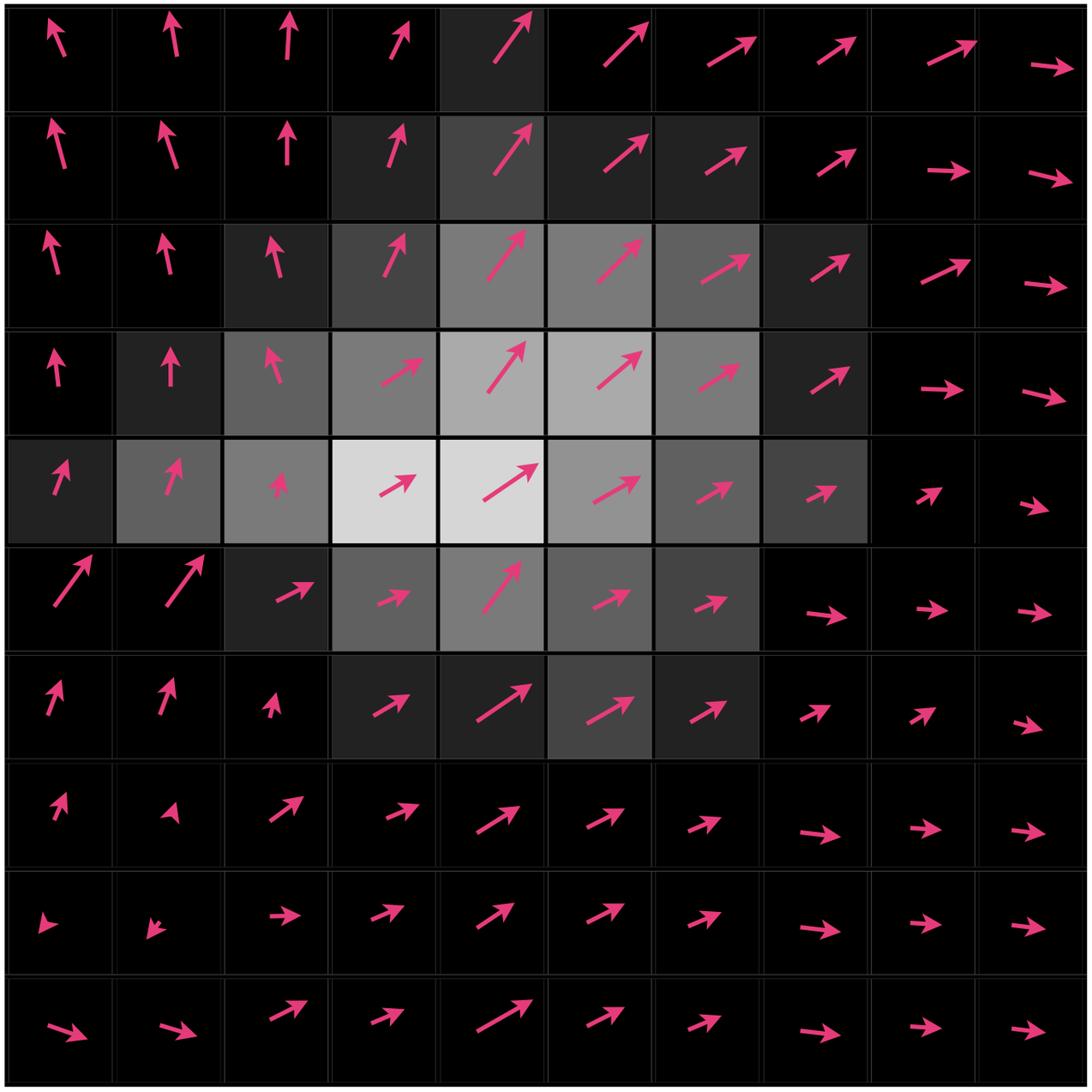


“Smoke in a box”

0	0	0	0	1	0	0	0	0	0
0	0	0	1	2	2	2	0	0	0
0	0	1	2	4	4	3	2	0	0
0	1	3	4	5	5	4	2	0	0
1	4	4	6	6	4	3	2	0	0
0	0	2	3	6	3	2	0	0	0
0	0	0	2	2	2	2	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

density field

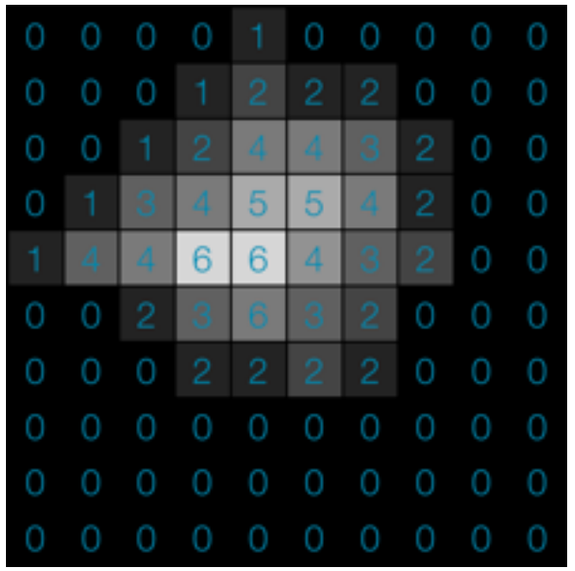
“Smoke in a box”



velocity field

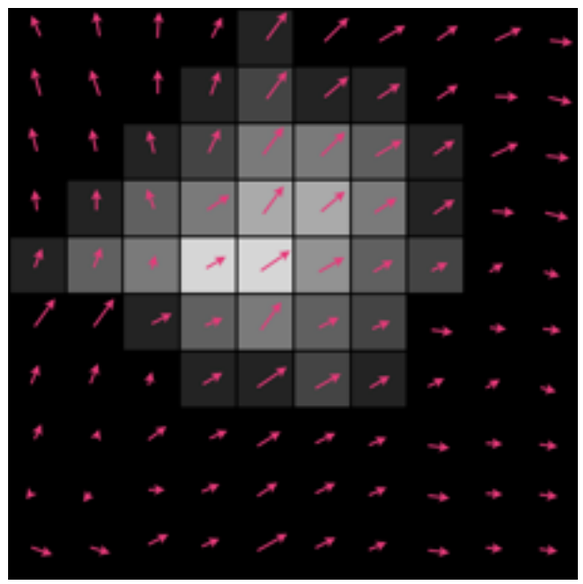
Processes

- The density field diffuses.
- The velocity field diffuses.



density

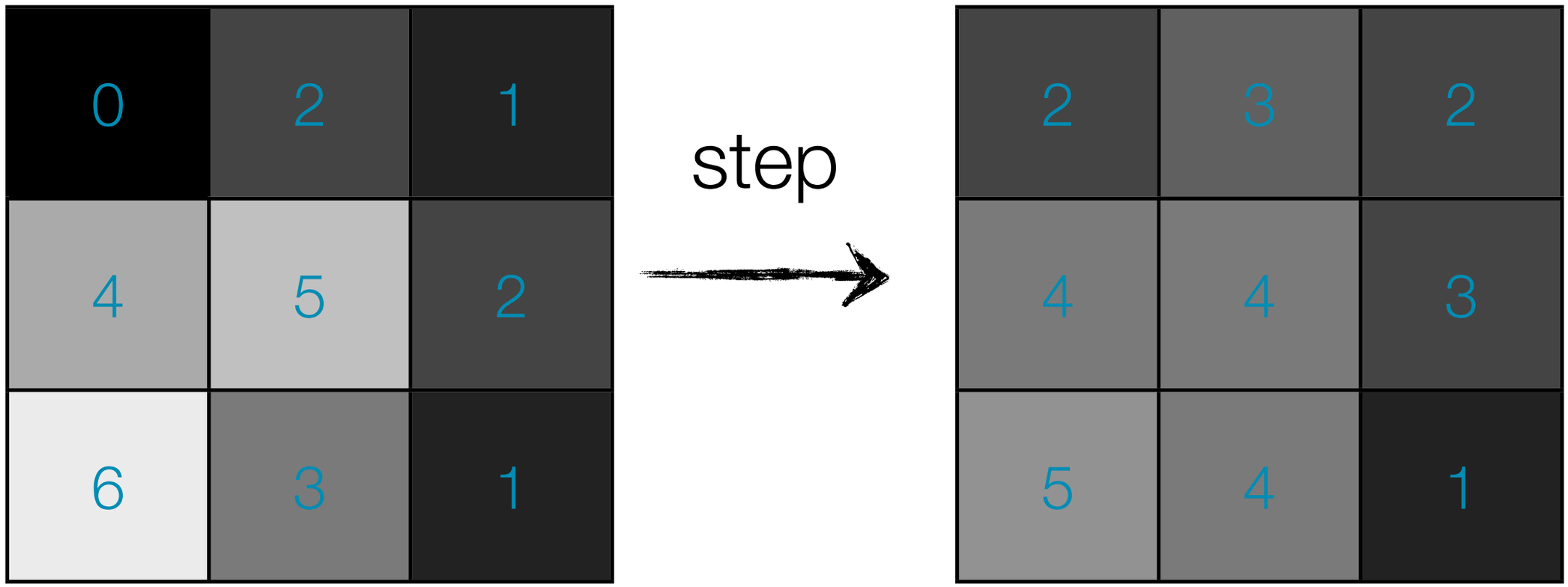
- The velocity field moves the density field.
- The velocity field moves itself.



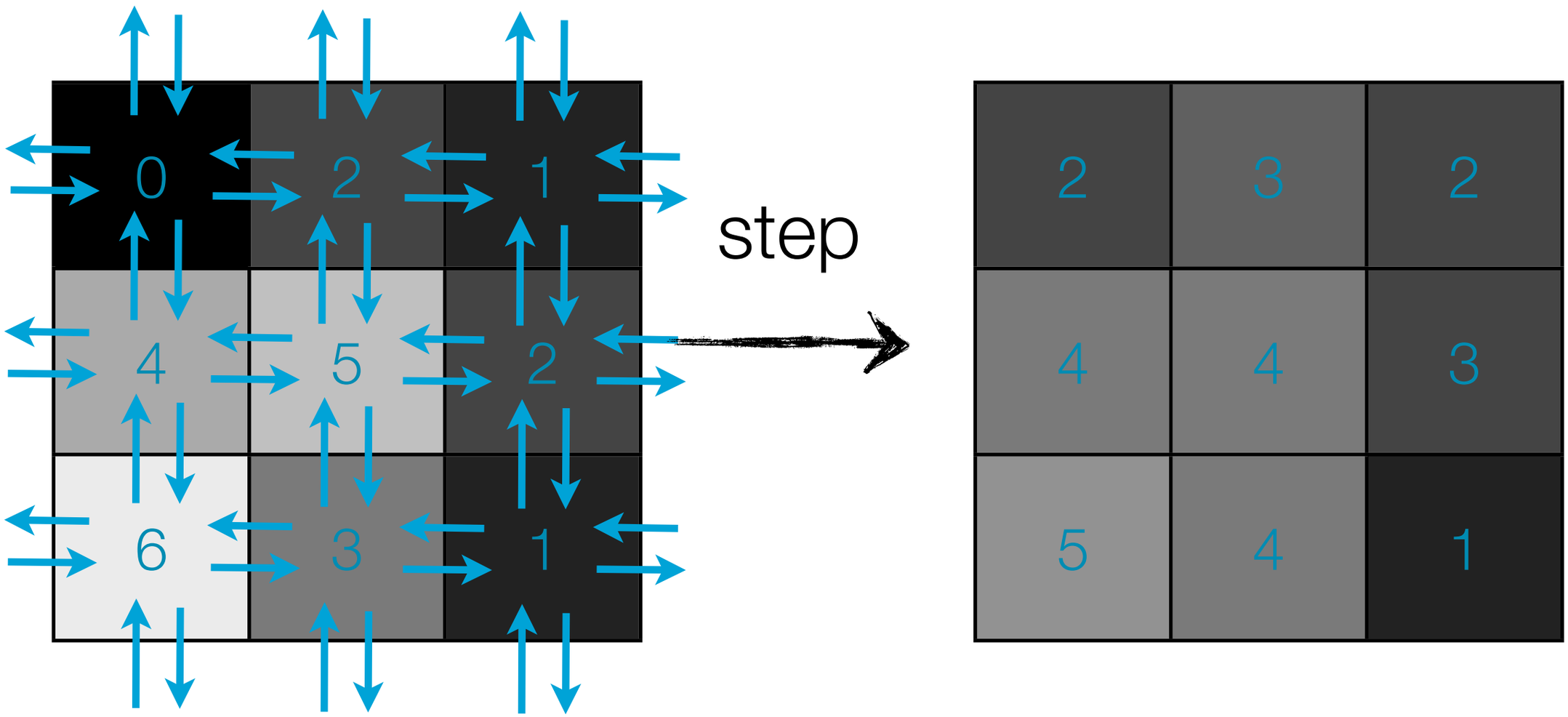
velocity

```
demo: ./Main -scale 3 -size 200 200 -visc 0 -diff 0 +RTS -N2 -qa -qg
```

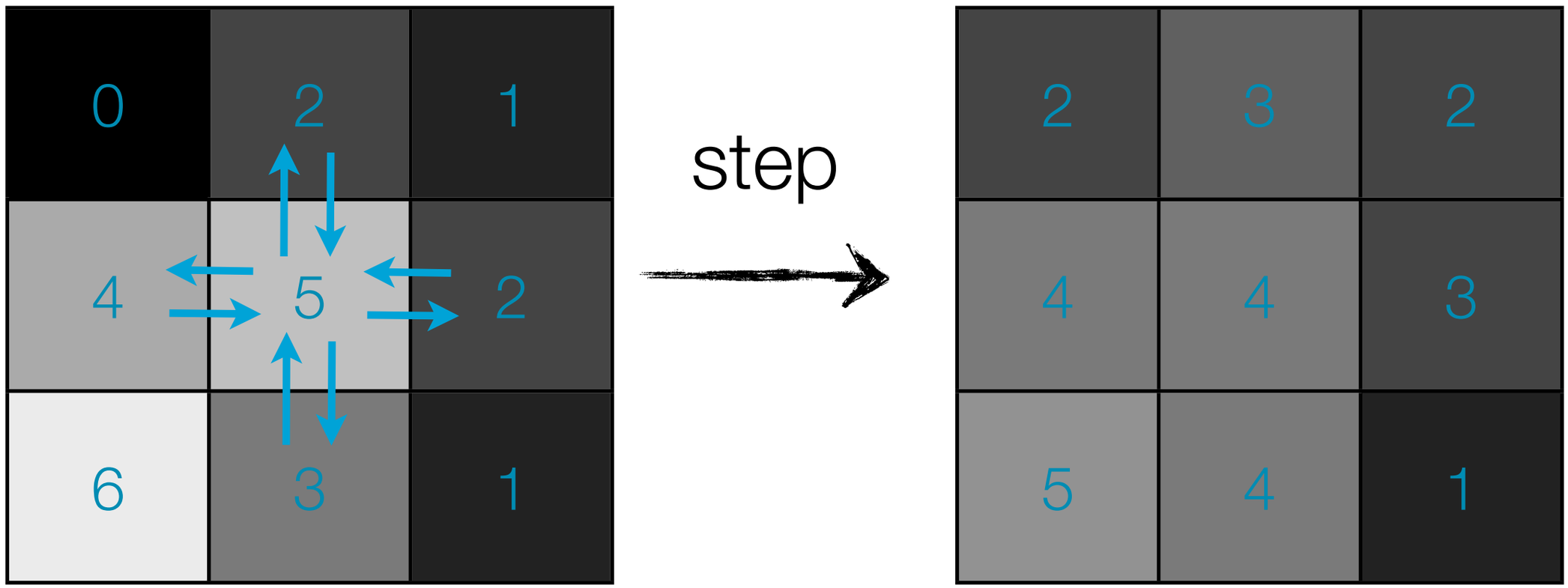
Density Diffusion



Density Diffusion

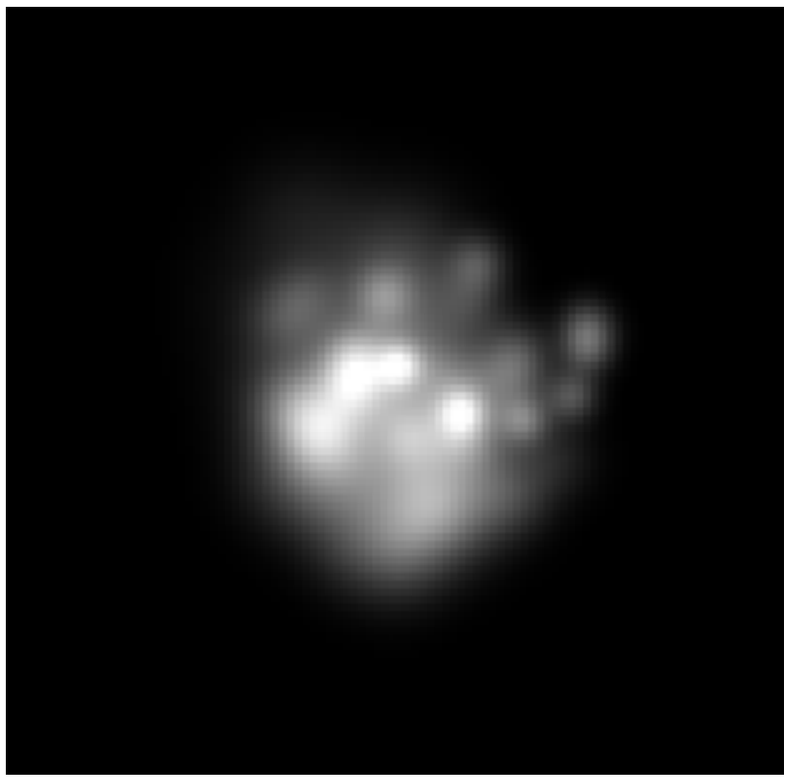


Density Diffusion

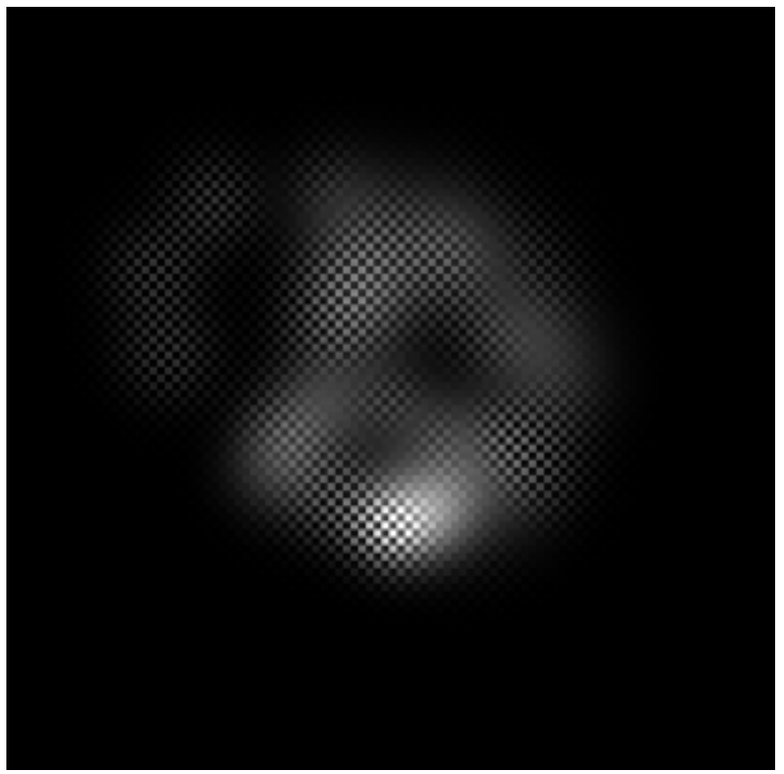


$$u'_{x,y} = u_{x,y} + a\,(u_{x-1,y} + u_{x+1,y} + u_{x,y-1} + u_{x,y+1} - 4 * u_{x,y})$$

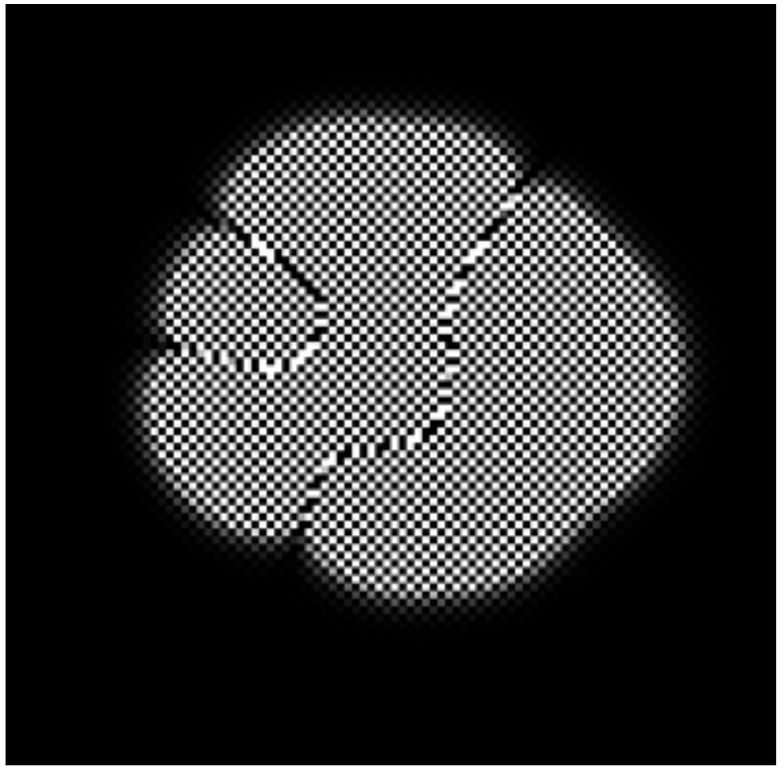
Stability



-delta 0.020



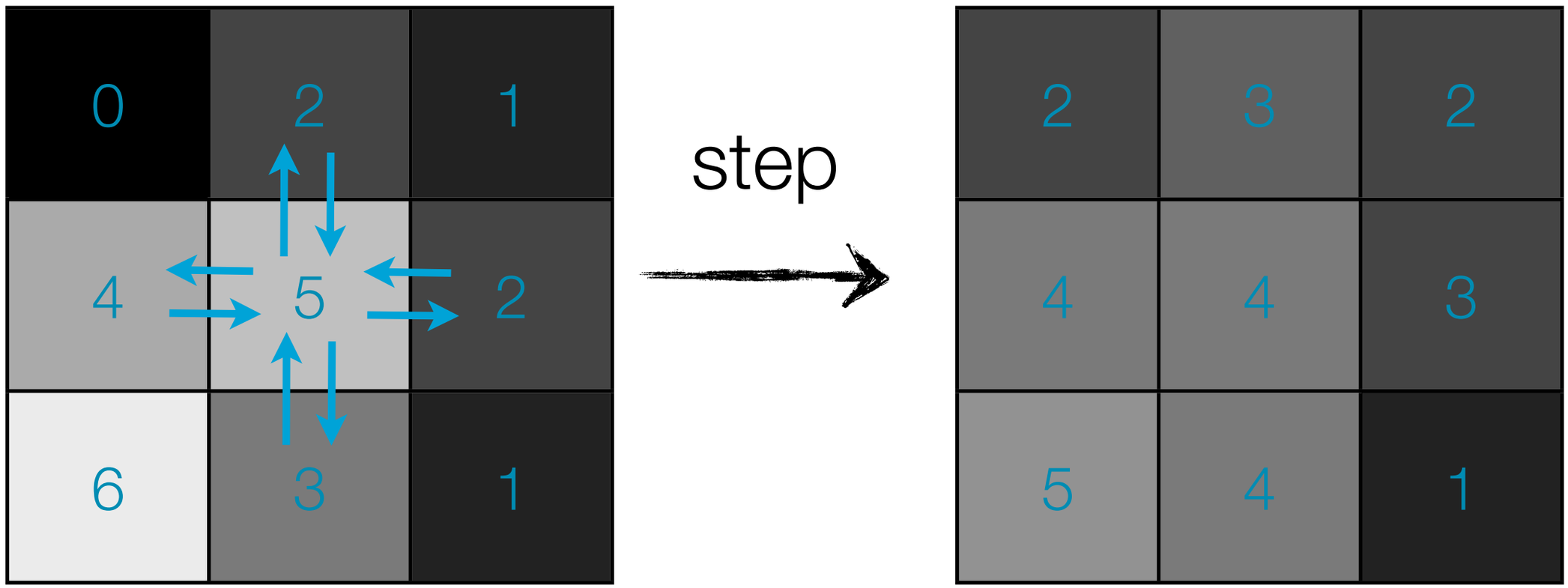
-delta 0.025



-delta 0.027

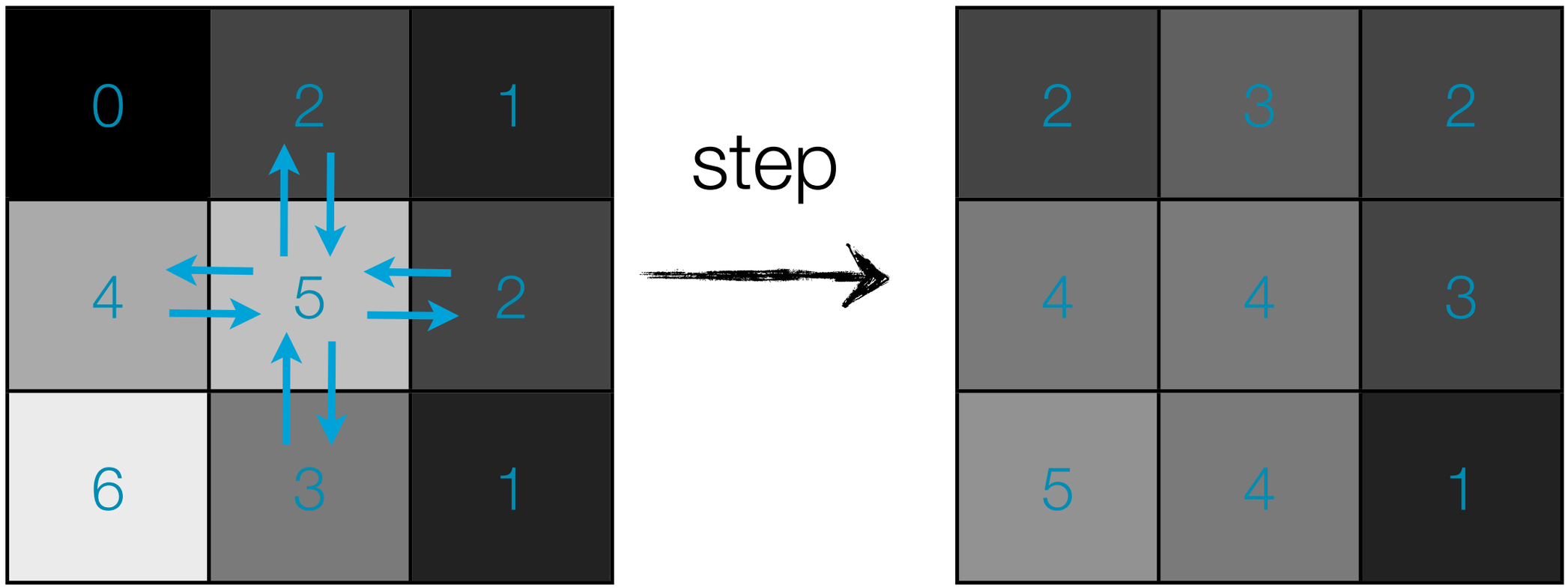
```
demo: ./Main -unstable -diff 0.001 -delta 0.02 -user-dens 500
```

Density Diffusion (unstable version)



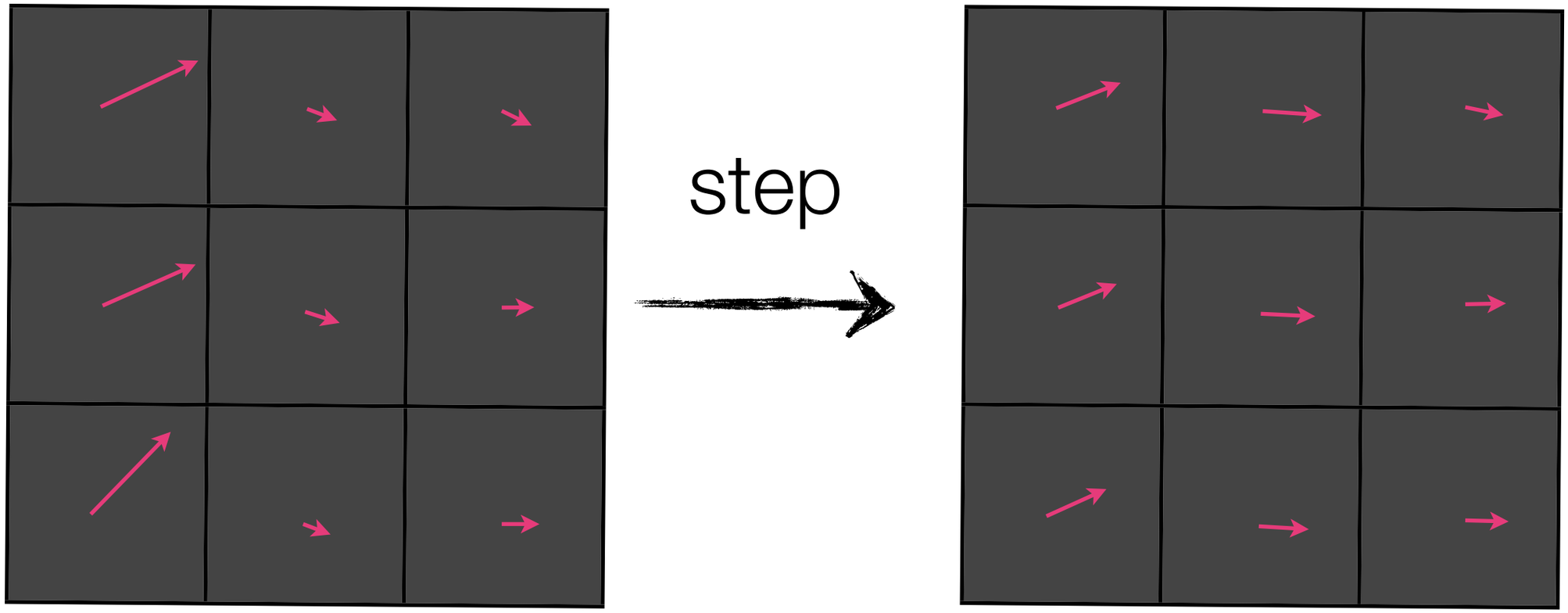
$$u'_{x,y} = u_{x,y} + a\,(u_{x-1,y} + u_{x+1,y} + u_{x,y-1} + u_{x,y+1} - 4 * u_{x,y})$$

Density Diffusion (stable version)



$$u'_{x,y} = (u_{x,y} + a (u'_{x-1,y} + u'_{x+1,y} + u'_{x,y-1} + u'_{x,y+1})) / (1 + 4 * a)$$

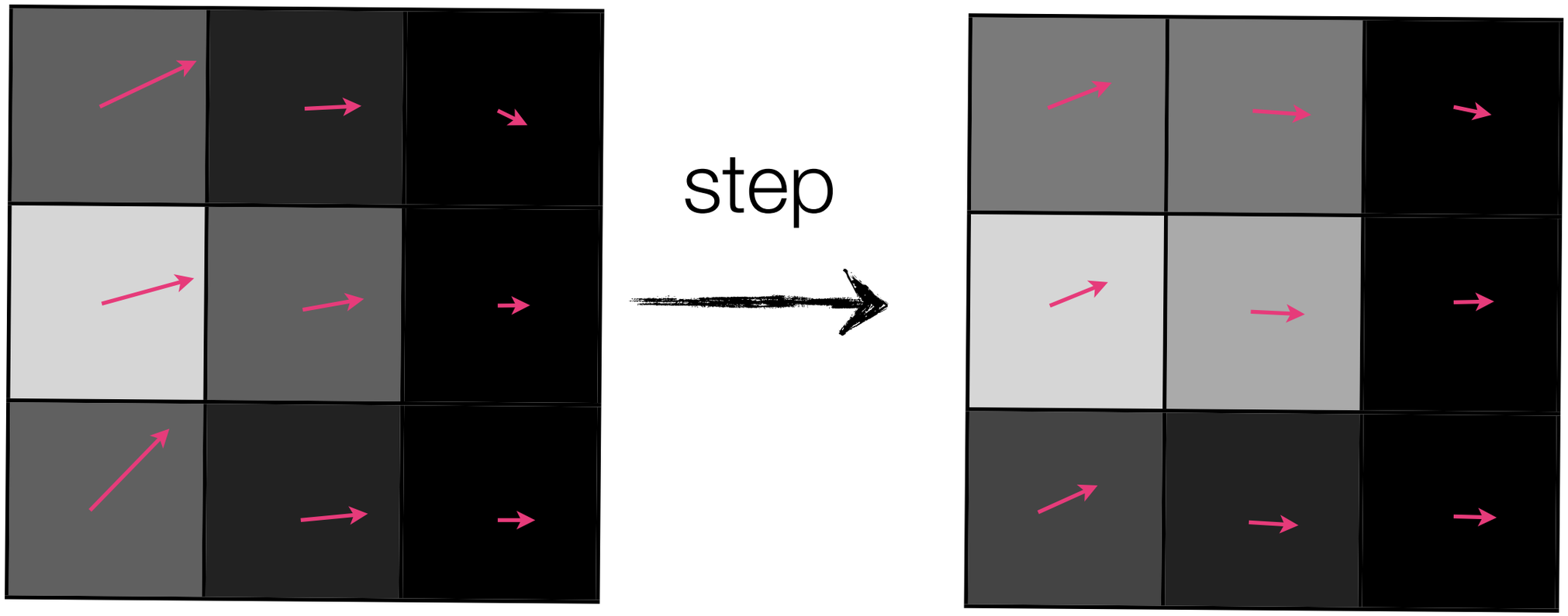
Velocity Diffusion (viscosity)



- Same idea as density diffusion.

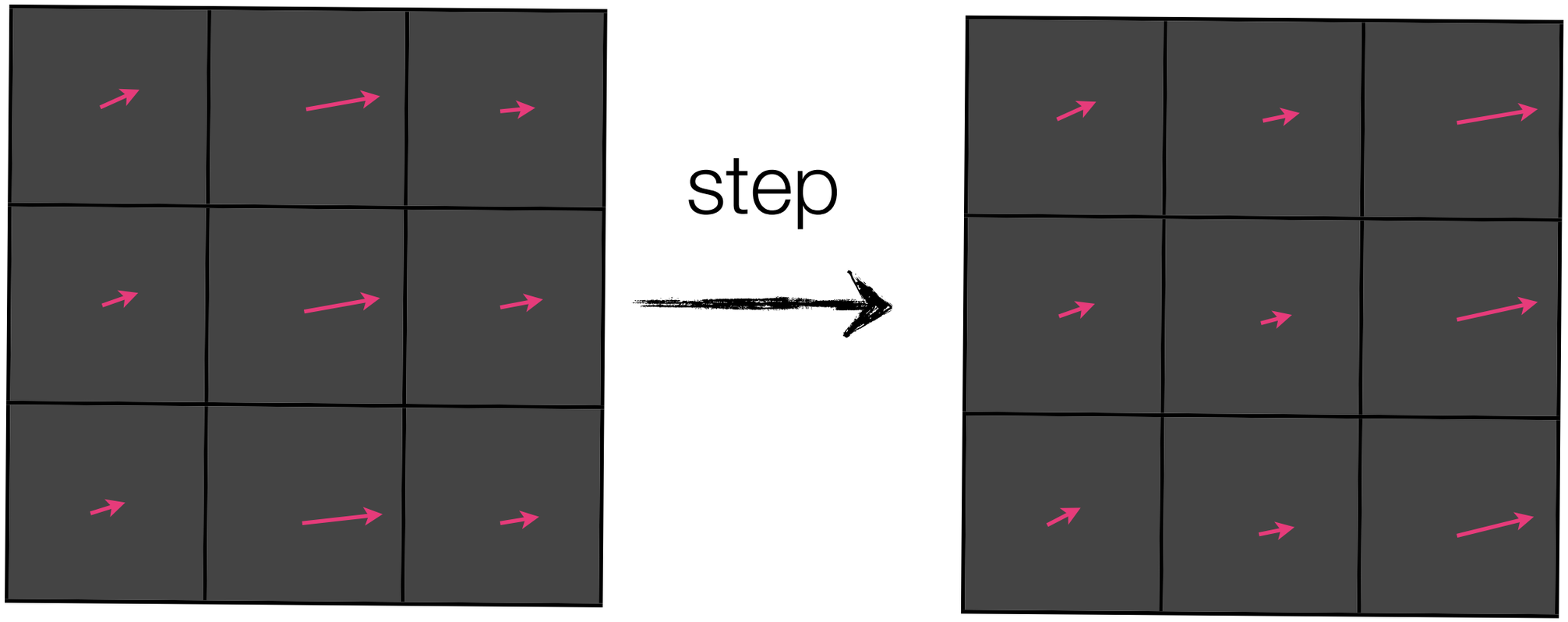
- Average out components of velocity vector among adjacent cells.

Density Advection



- The velocity field moves the density field.

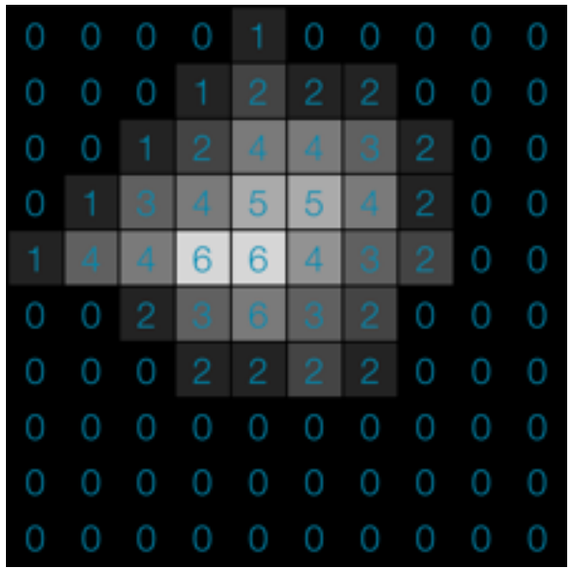
Velocity Advection



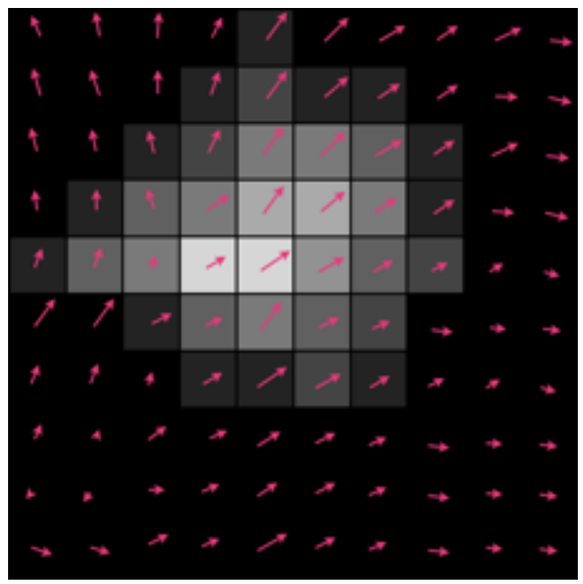
- The velocity field moves itself.

Processes (again)

- The density field diffuses.
- The velocity field diffuses.
- The velocity field moves the density field.
- The velocity field moves itself.

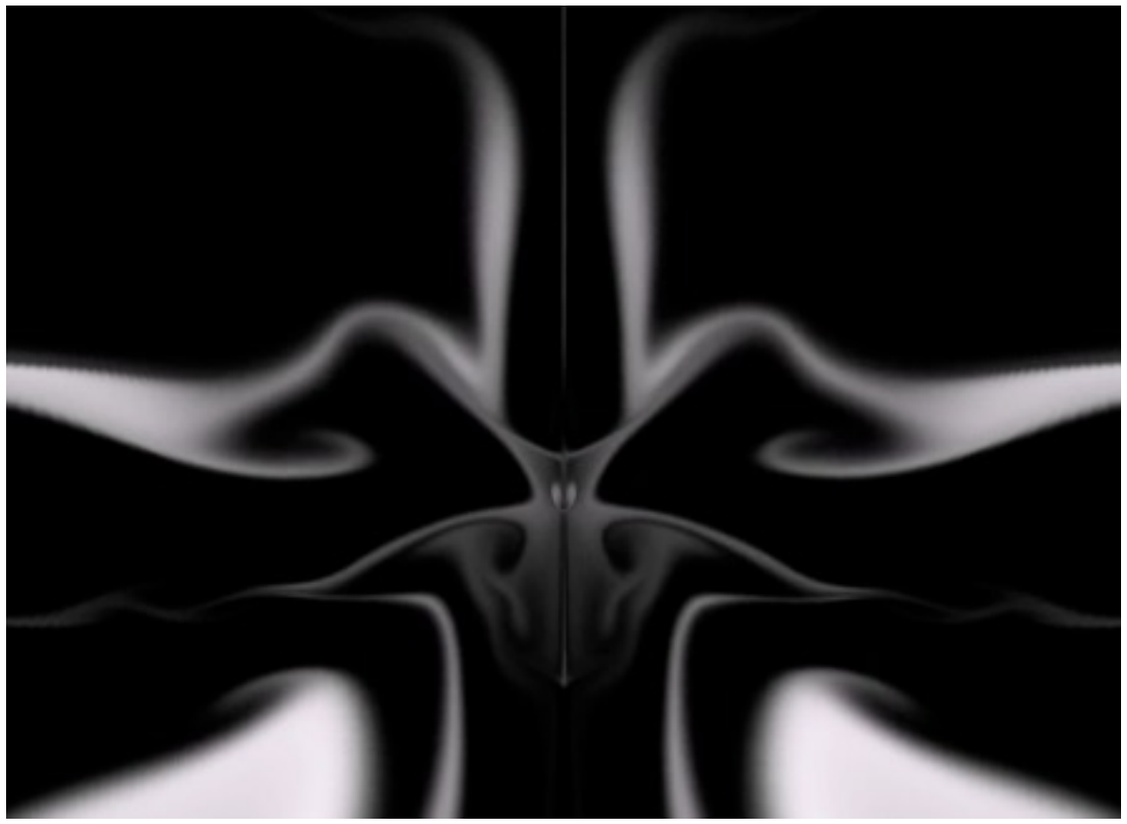


density



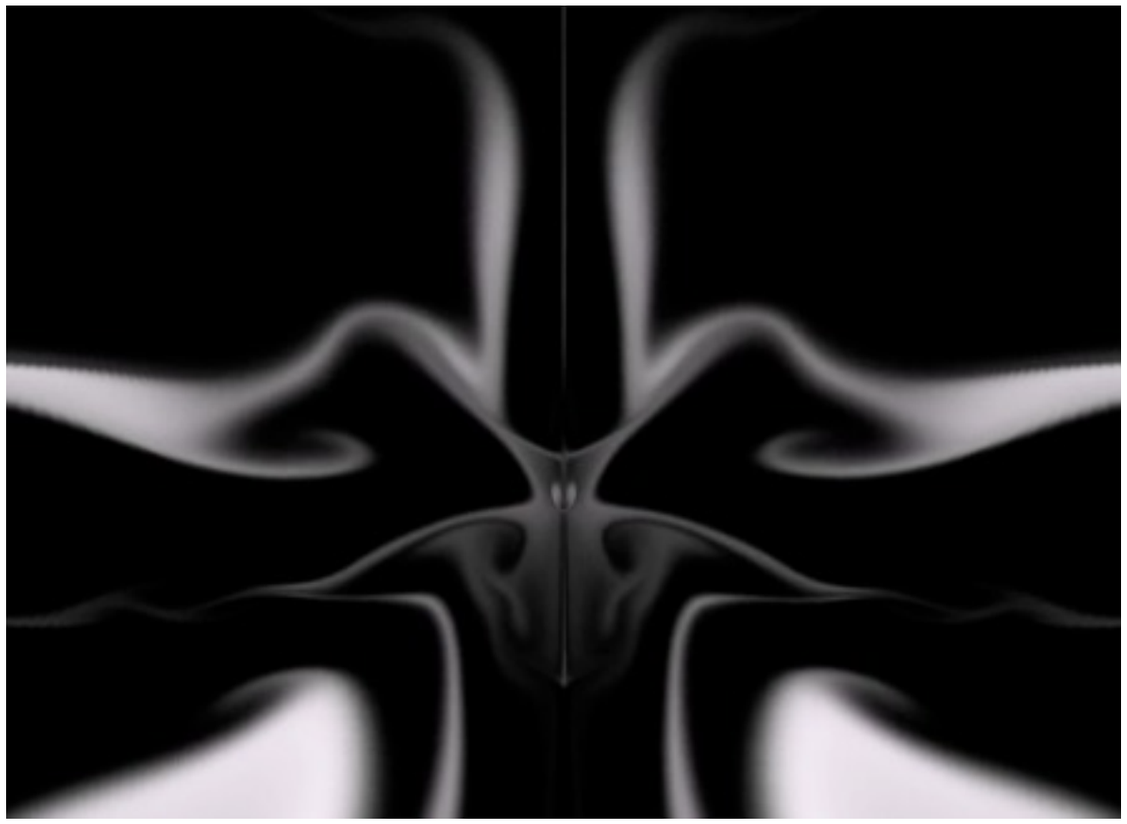
velocity

Astro Elk



- Set diffusion and viscosity to zero.
- Use high number of iterations so simulation is stable.
- Apply lens effect to resulting fluid matrix.

Astro Elk



- Try many initial conditions until it does something interesting.
- Increase diffusion at end so we get a fade-out effect.
- Render individual frames, combine into video with ffmpeg.

Loss of detail at low iteration numbers

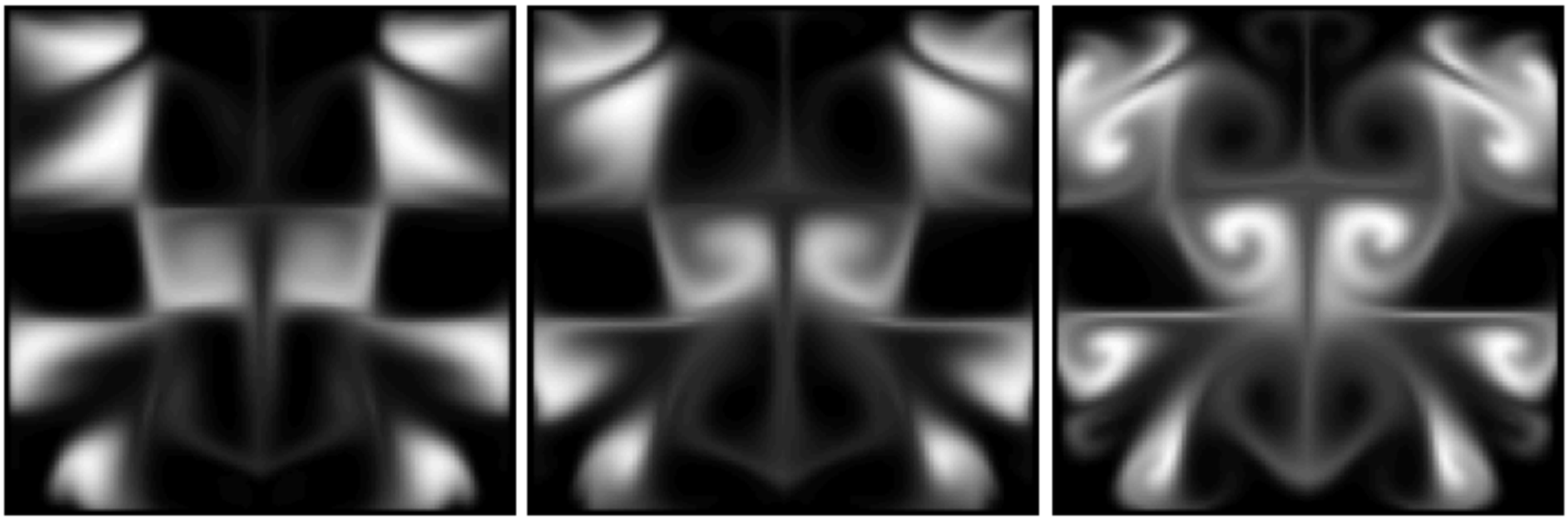
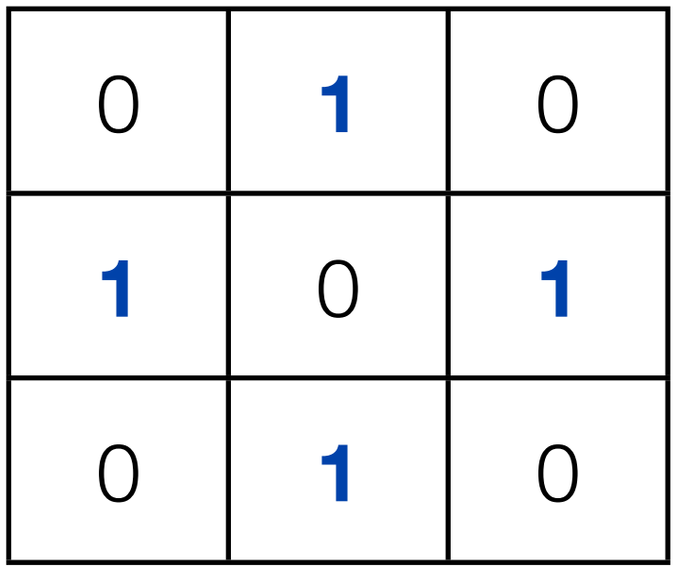


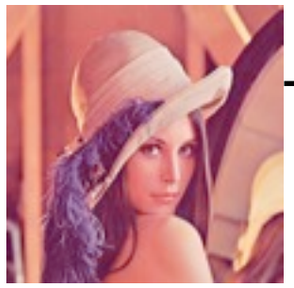
Figure 9. Fluid Solver output for 4, 10, and 100 Jacobi iterations.

Efficient Parallel Stencil Convolution

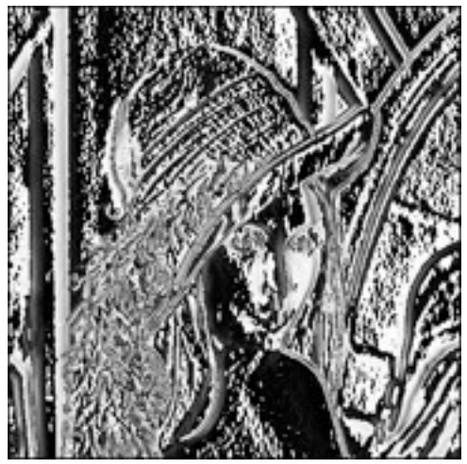
$$
\begin{aligned}
u'_{x,y} \\
&= (\; u_{x,y} \\
&\quad + a \; (\mathbf{u'_{x-1,y} + u'_{x+1,y} + u'_{x,y-1} + u'_{x,y+1}})) \\
&\qquad / \; (1 + 4 * a)
\end{aligned}
$$



Canny Edge Detection

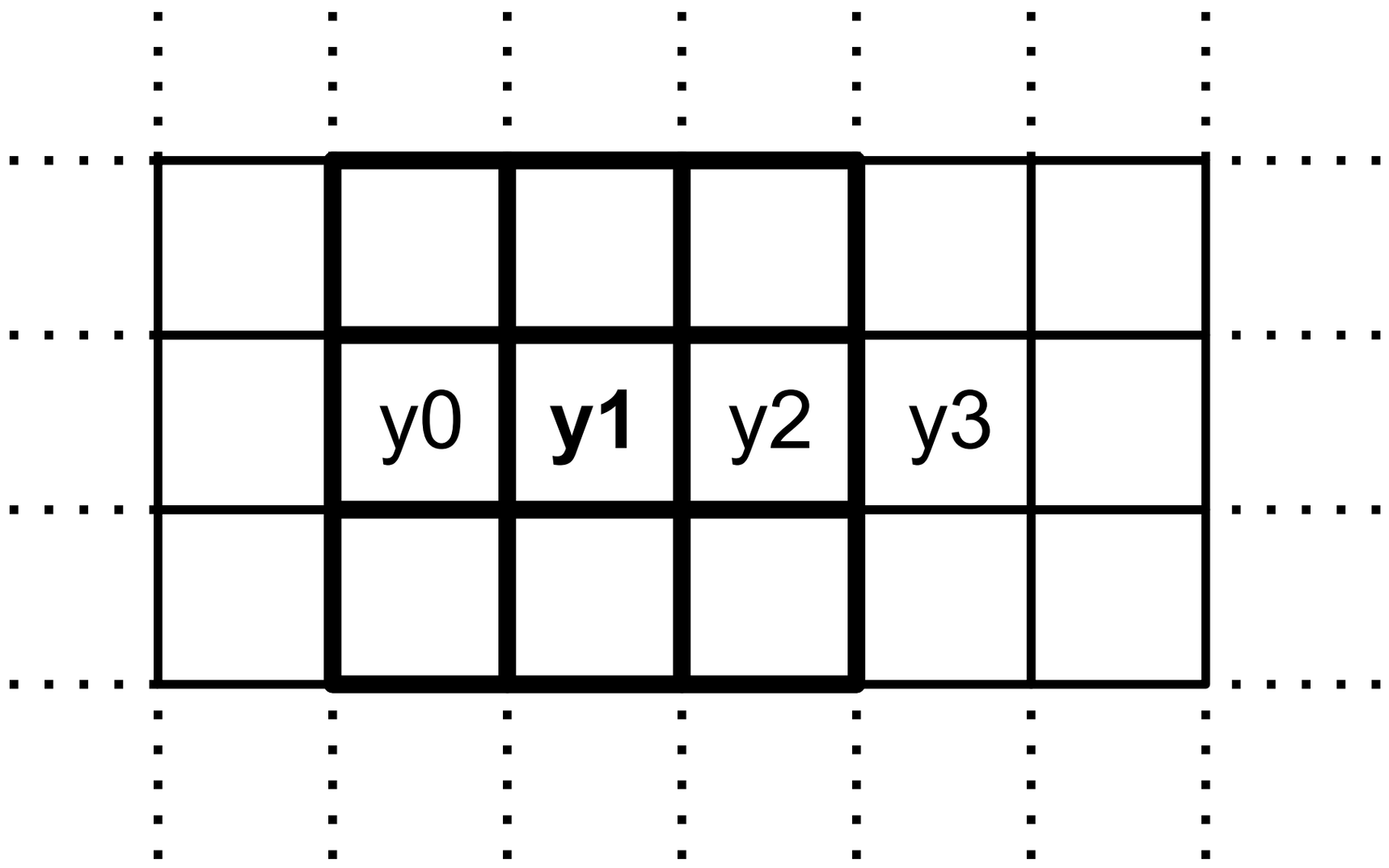


GreyScale → Blur → Differentiate → (dashed)



(dashed) → Mag / Dir → Maxima → Link Edges

Sharing in computations of adjacent pixels.



4*9 = 36

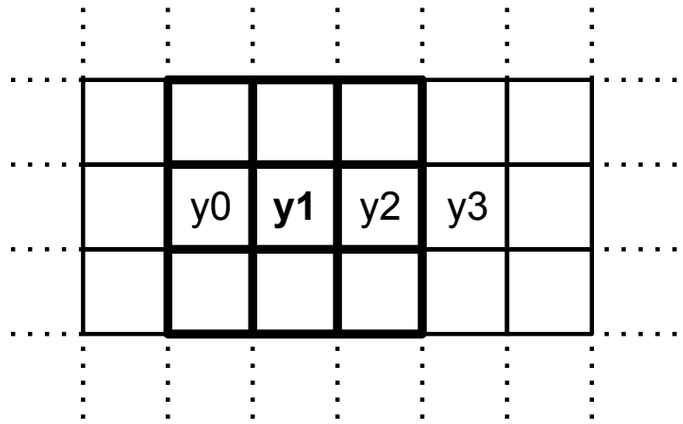
3*6 = 18

36 / 18 = 2

Source Stencil Definition

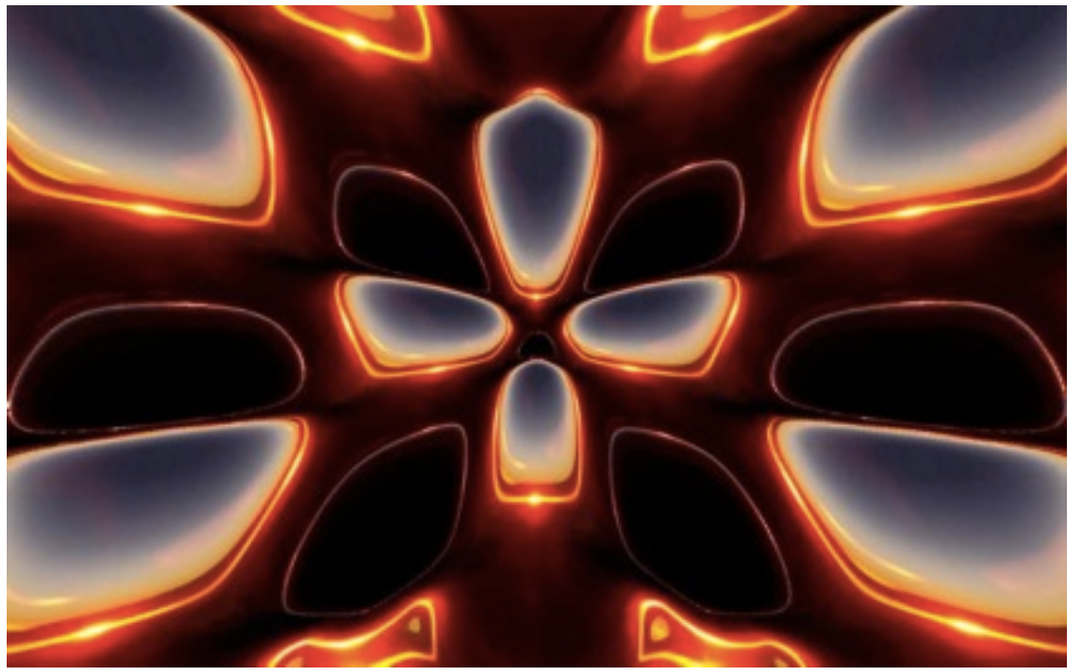
```
laplace :: Stencil sh a
laplace = [stencil2| 0 1 0
                     1 0 1
                     0 1 0 |]
```

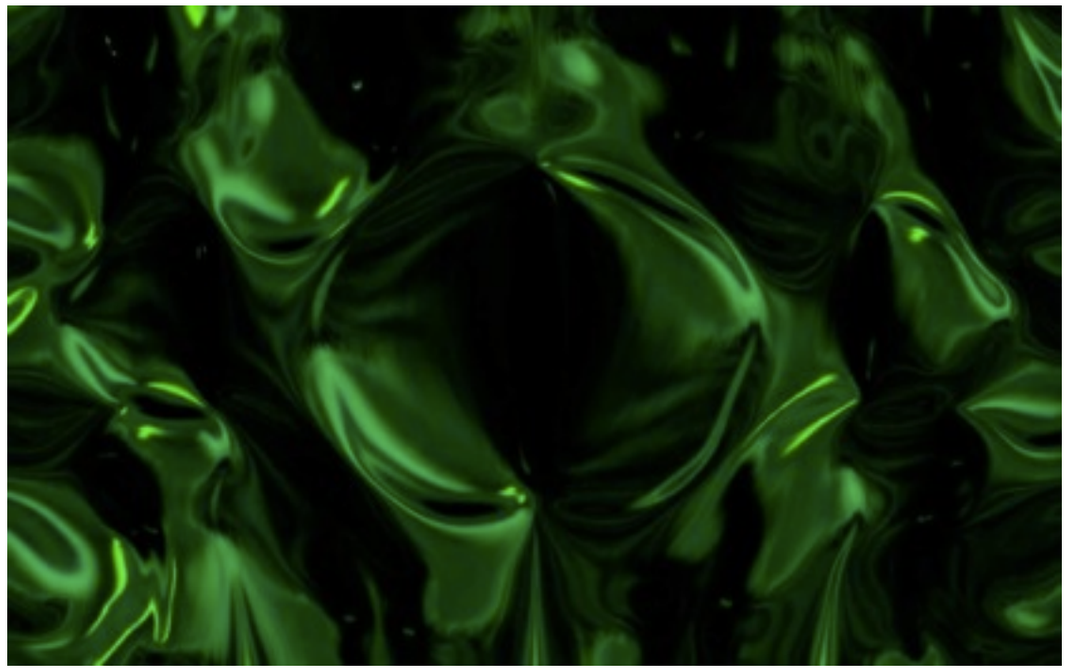
```
  09b0 mov    0x2e(rbx), rcx
  09b4 mov    0x1e(rbx), rdx
  09b8 mov    rdx, rsi
  09bb imul   rcx, rsi
  09bf mov    0x36(rbx), rdi
  09c3 lea    0x4(r14,rdi,1), r8
  09c8 add    r14, rdi
  09cb lea    0x1(rcx), r9
  09cf imul   rdx, r9
  09d3 lea    0x2(r9,rdi,1), r10
  09d8 mov    0x6(rbx), r11
  09dc mov    0xe(rbx), r15

L 09e0 movss  0x10(r15,r10,4), xmm7
  09e7 lea    (r8,r9,1), r10
L 09eb movss  0x10(r15,r10,4), xmm8
  09f2 subss  xmm7, xmm8
  09f7 lea    (r8,rsi,1), r10
L 09fb movss  0x10(r15,r10,4), xmm9
  0a02 addss  xmm9, xmm9
  0a07 addss  xmm8, xmm9
  0a0c lea    0x2(rsi,rdi,1), r10
L 0a11 movss  0x10(r15,r10,4), xmm8
  0a18 movaps xmm8, xmm10
  0a1c mulss  xmm0, xmm10
  0a21 addss  xmm9, xmm10
  0a26 dec    rcx
  0a29 imul   rdx,rcx
  0a2d add    rcx,r8

L 0a30 addss  0x10(r15,r8,4), xmm10
  0a37 lea    0x1(r9,rdi,1), rdx
L 0a3c movss  0x10(r15,rdx,4), xmm9
  0a43 lea    0x3(r9,rdi,1), rdx
L 0a48 movss  0x10(r15,rdx,4), xmm11
  0a4f subss  xmm9, xmm11
  0a54 lea    0x3(rsi,rdi,1), rdx
L 0a59 movss  0x10(r15,rdx,4), xmm12
  0a60 addss  xmm12, xmm12
  0a65 addss  xmm11, xmm12
  0a6a lea    0x1(rsi,rdi,1), rdx
L 0a6f movss  0x10(r15,rdx,4), xmm11
  0a76 movaps xmm11, xmm13
  0a7a mulss  xmm0, xmm13
  0a7f addss  xmm12, xmm13
  0a84 lea    0x3(rcx,rdi,1), rdx
L 0a89 addss  0x10(r15,rdx,4), xmm13

  0a90 lea    (rdi,r9,1), rdx
L 0a94 subss  0x10(r15,rdx,4), xmm7
  0a9b addss  xmm8, xmm8
  0aa0 addss  xmm7, xmm8
  0aa5 lea    0x1(rcx,rdi,1), rdx
  0aaa lea    0x2(rcx,rdi,1), r8
  0aaf lea    (rdi,rsi,1), r10
L 0ab3 movss  0x10(r15,r10,4), xmm7
  0aba mulss  xmm0, xmm7
  0abe addss  xmm8, xmm7
L 0ac3 movss  0x10(r15,r8,4), xmm8
  0aca addss  xmm8, xmm7
  0acf lea    (rdi,rcx,1), r8
L 0ad3 subss  0x10(r15,r8,4), xmm7
```

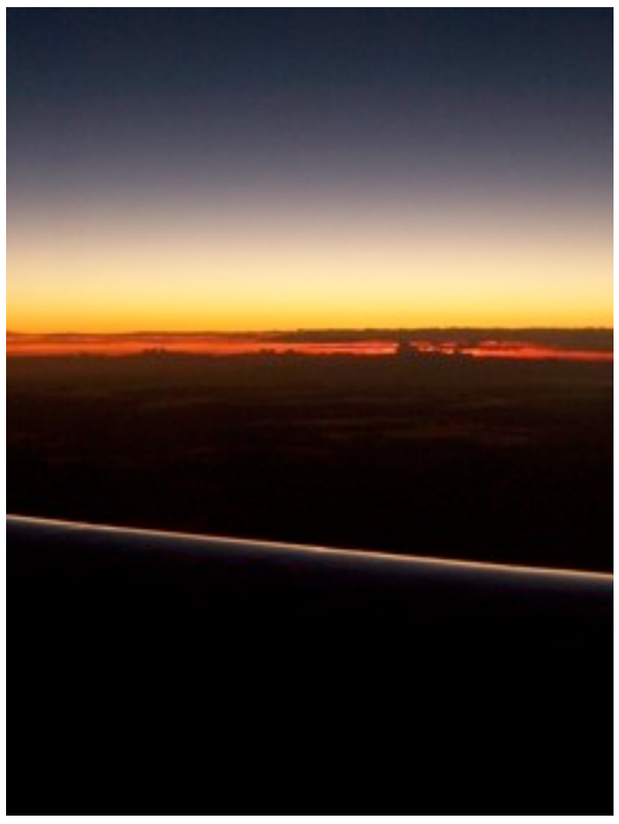



```
  0ada add    rax, rdi
  0add add    rdi, r9
L 0ae0 subss 0x10(r15,r9,4), xmm9
  0ae7 addss xmm11, xmm11
  0aec addss xmm9, xmm11
  0af1 lea    (rdi,rsi,1), r8
L 0af5 movss 0x10(r15,r8,4), xmm9
  0afc mulss xmm0, xmm9
  0b01 addss xmm11, xmm9
L 0b06 movss 0x10(r15,rdx,4), xmm11
  0b0d addss xmm11, xmm9
  0b12 add    rcx, rdi
L 0b15 subss 0x10(r15,rdi,4), xmm9

  0b1c add    r14,rsi
S 0b1f movss xmm9,0x10(r11,rsi,4)
  0b26 mov    0x6(rbx),rcx
S 0b2a movss xmm7,0x14(rcx,rsi,4)
  0b30 subss xmm11,xmm13
  0b35 mov    0x6(rbx),rcx
S 0b39 movss xmm13,0x18(rcx,rsi,4)
  0b40 subss xmm8,xmm10
  0b45 mov    0x6(rbx),rcx
S 0b49 movss xmm10,0x1c(rcx,rsi,4)
  0b50 lea    0x8(r14),rcx
  0b54 lea    0x4(r14),r14
  0b58 cmp    0x26(rbx),rcx
  0b5c jle    9b0
```

Image based videos







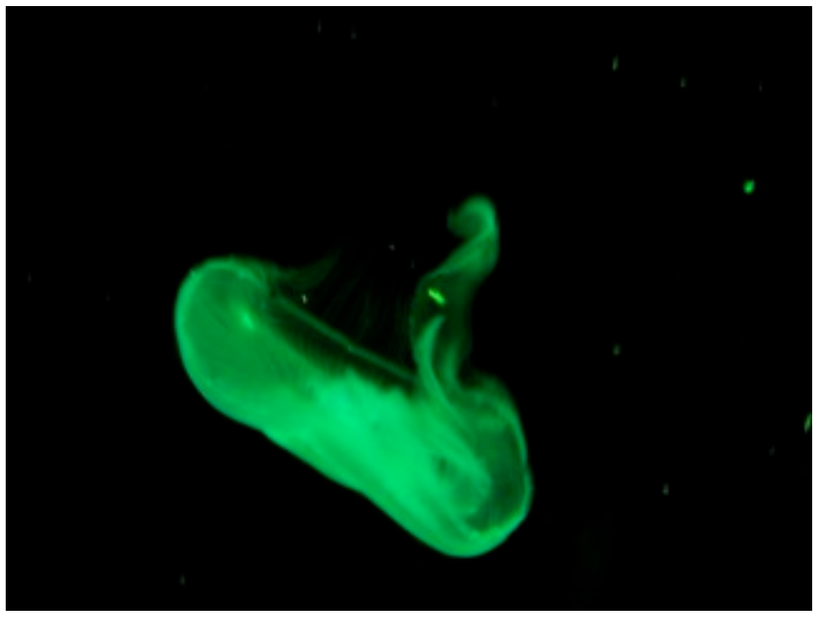
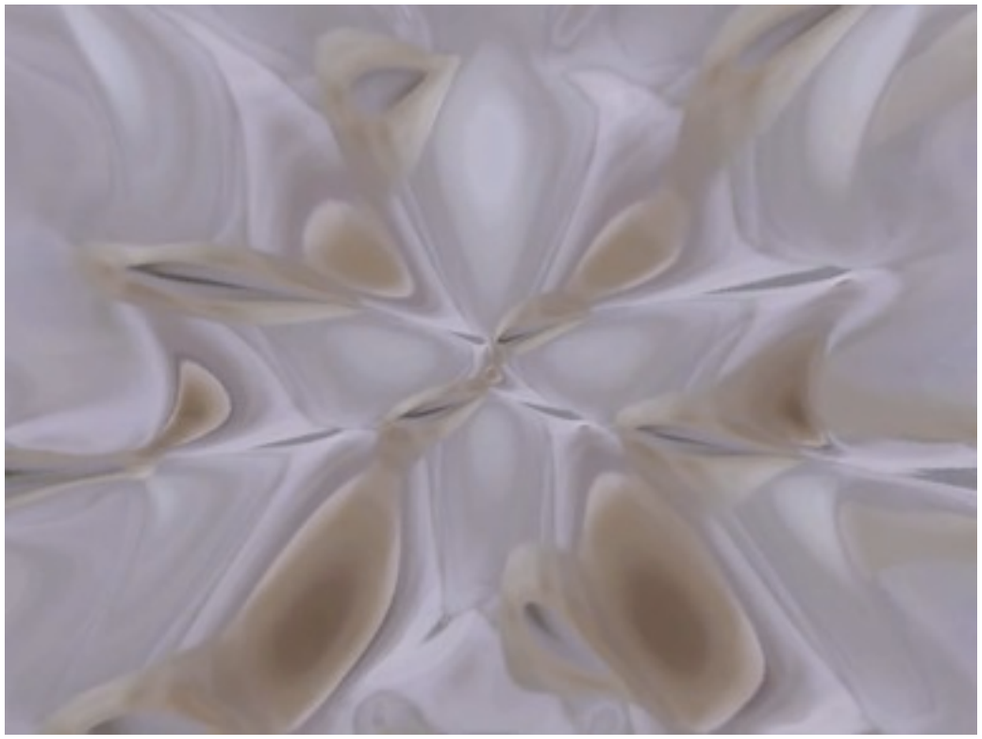
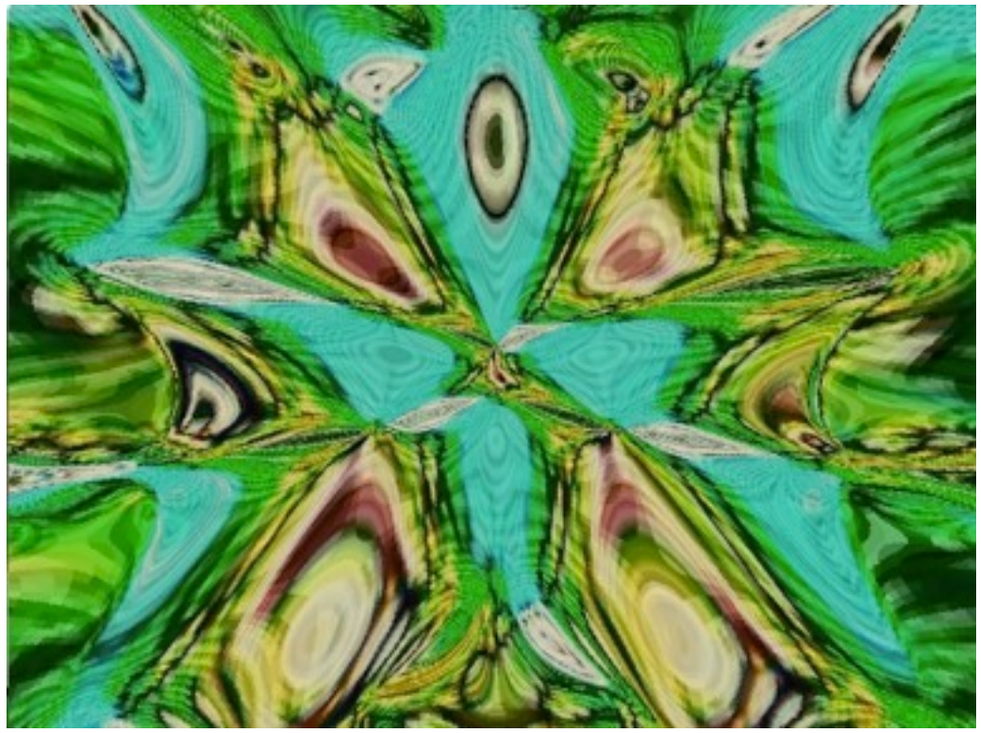
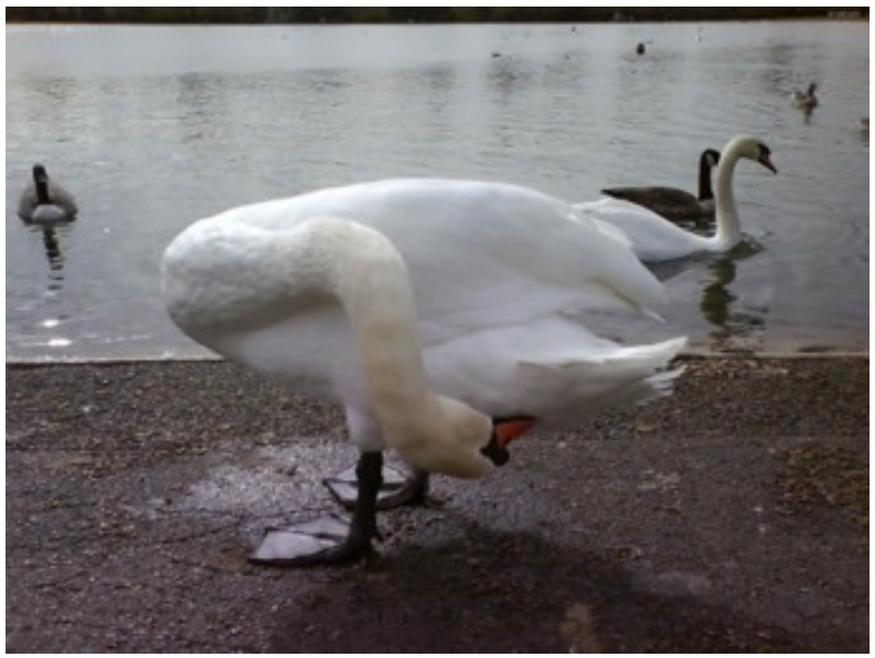
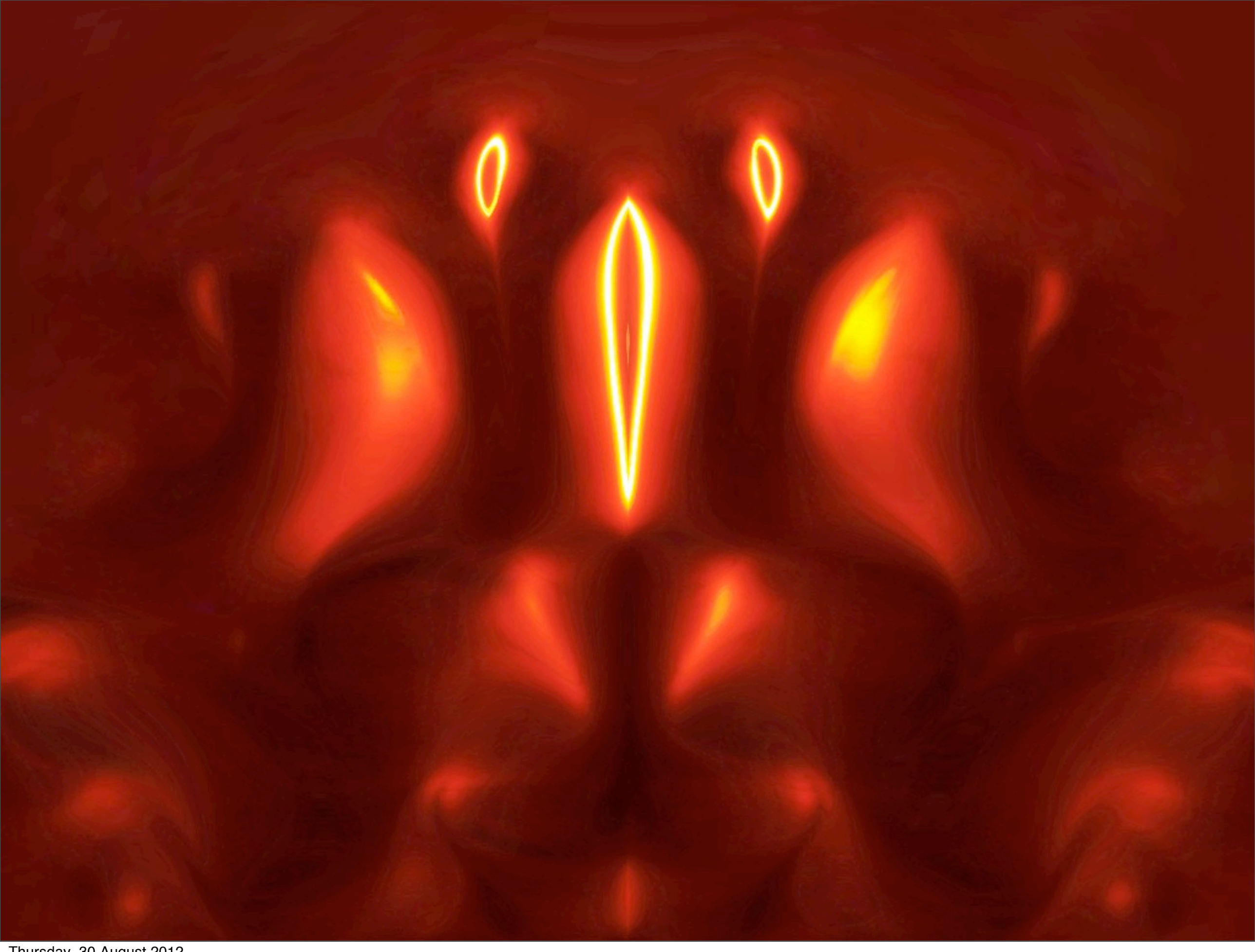


Image based videos









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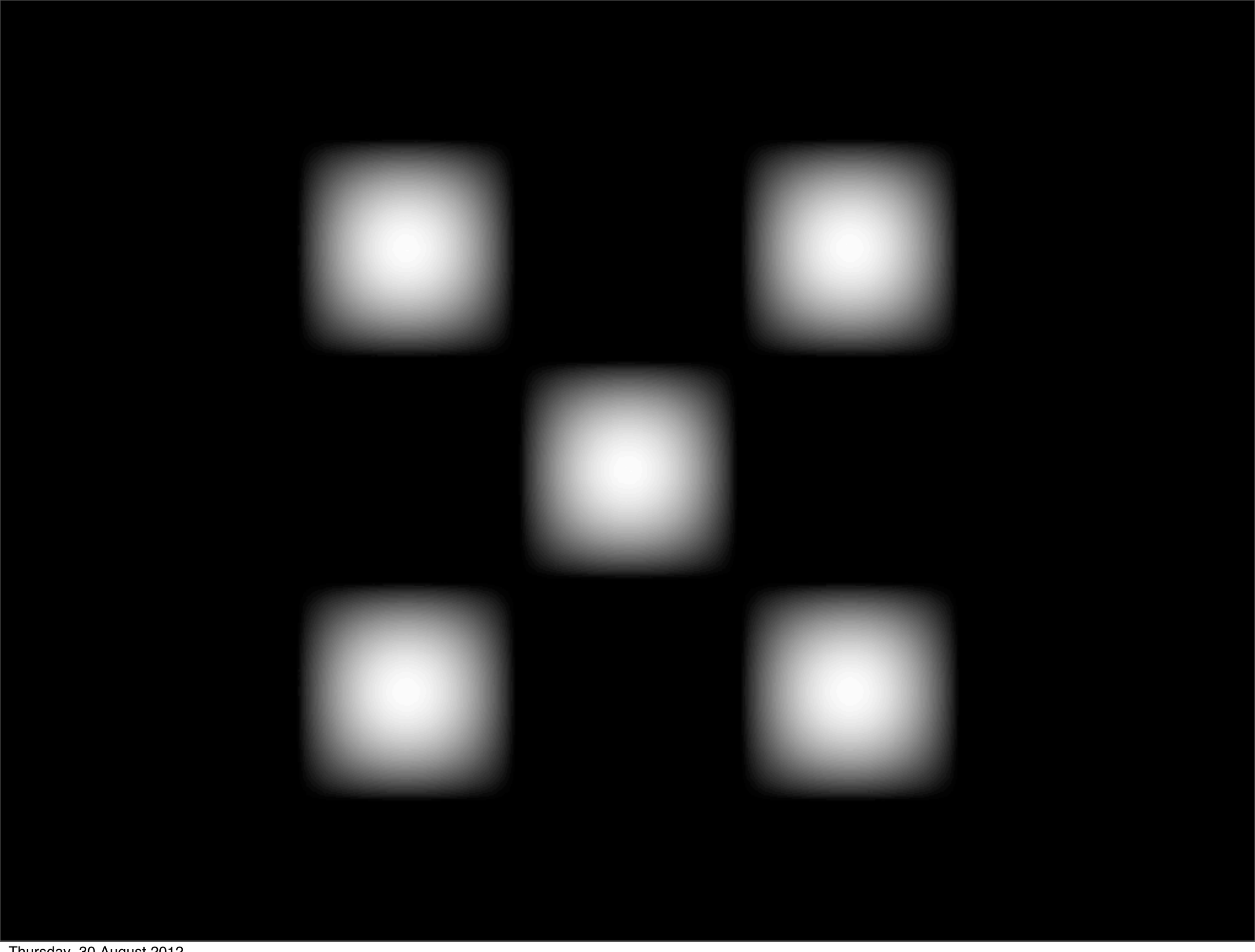

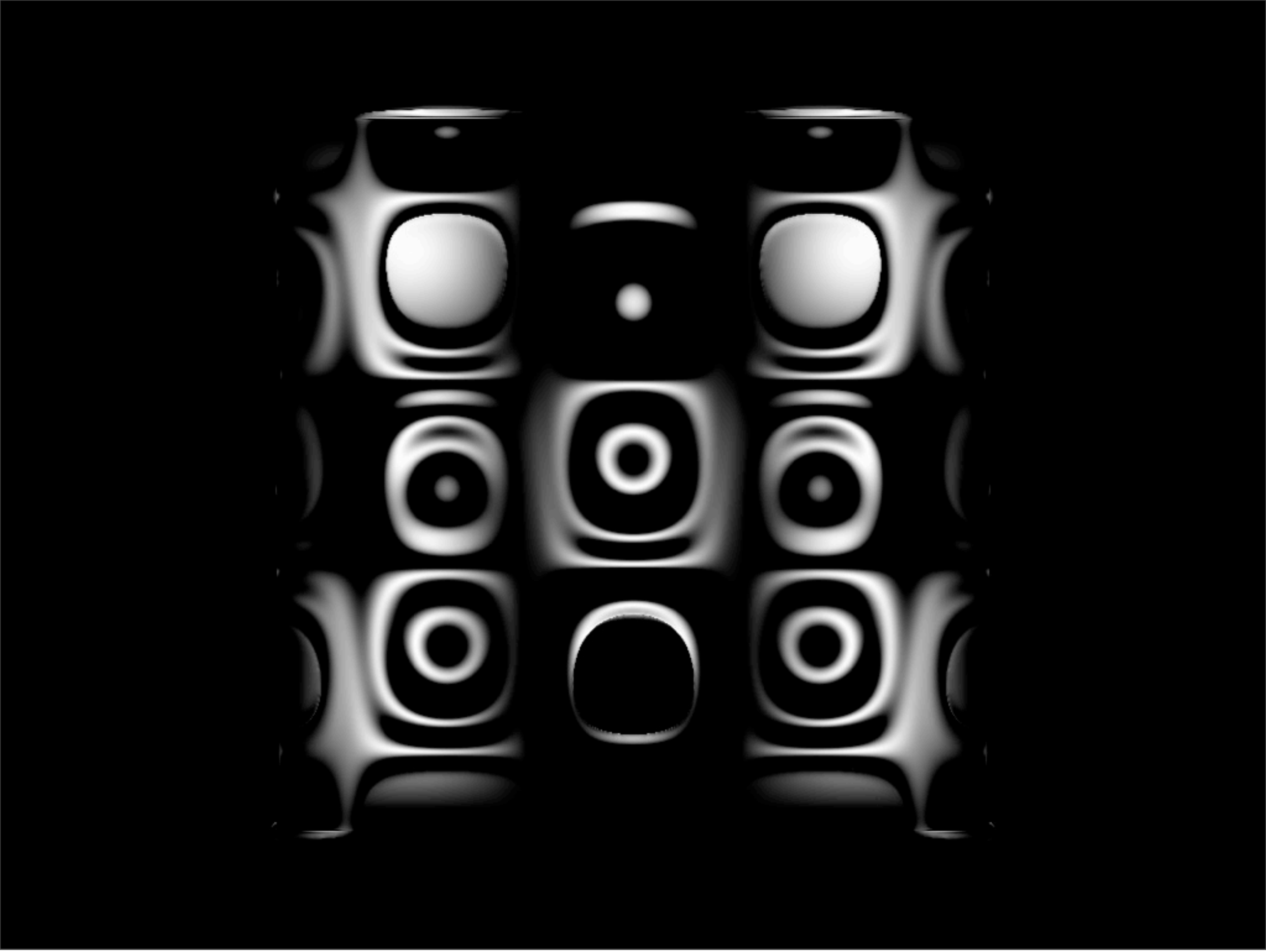

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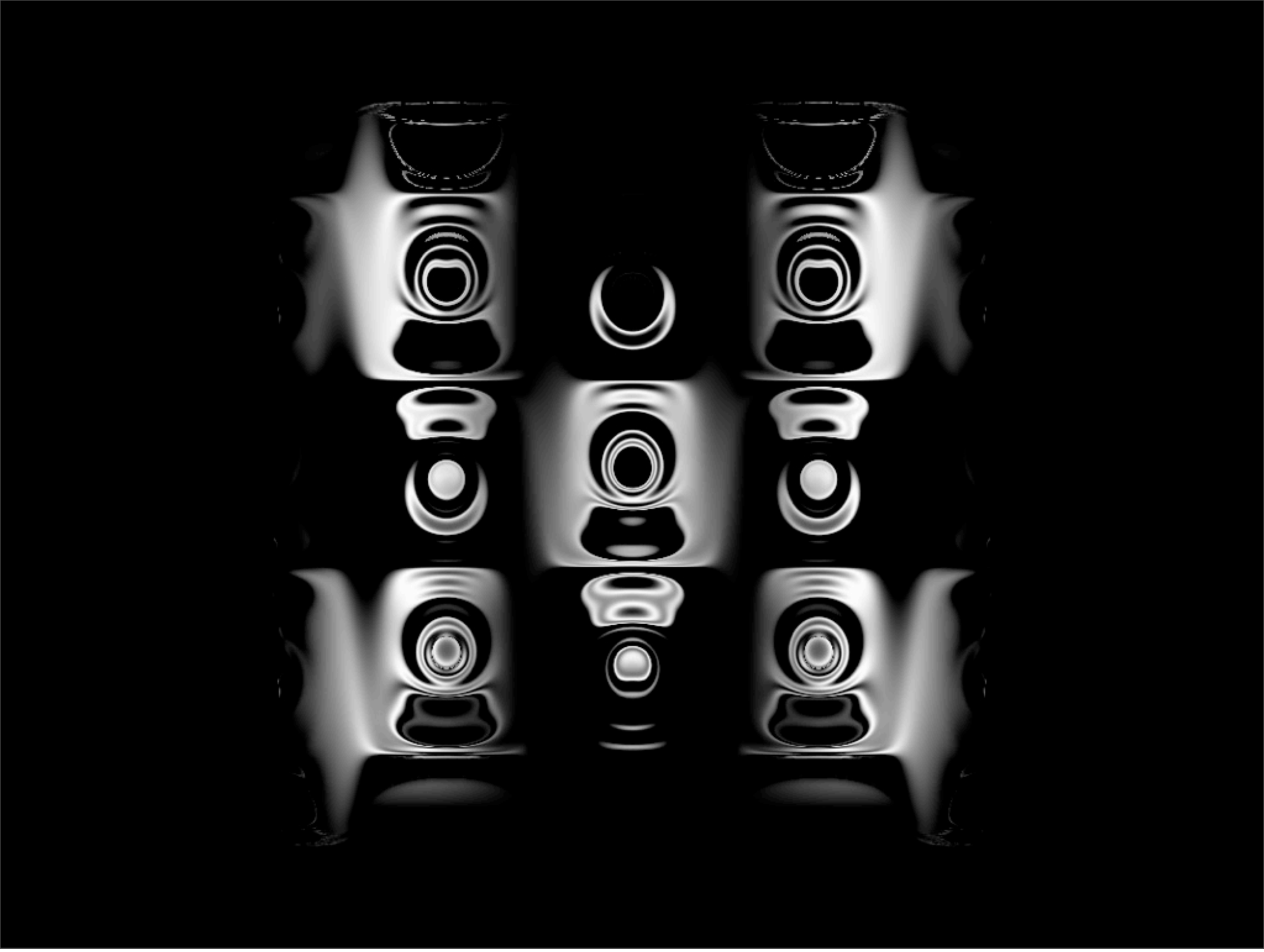

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