Intermediate Graphics & Animation Programming

GPR-300
Daniel S. Buckstein

Bloom & High Dynamic Range Rendering
Week 5

License

HDRR & Bloom

- High Dynamic Range (HDR) photography
- High Dynamic Range Rendering (HDRR)
- HDR Bloom
  - Box blur
  - Bright pass
  - Gaussian blur
  - Compositing
- Optimizations and improvements

HDR Photography

- HDR: ***High Dynamic Range Imaging***
- Uses the principle of "*tone mapping*"
- Combining several ranges of colour into one

Daniel S. Buckstein

https://en.wikipedia.org/wiki/Tone_mapping


5
138
331
62


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Any travel on Points.
First Class
VISA
Now that's First Class.
TD Canada Trust
milestones
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What did you get?

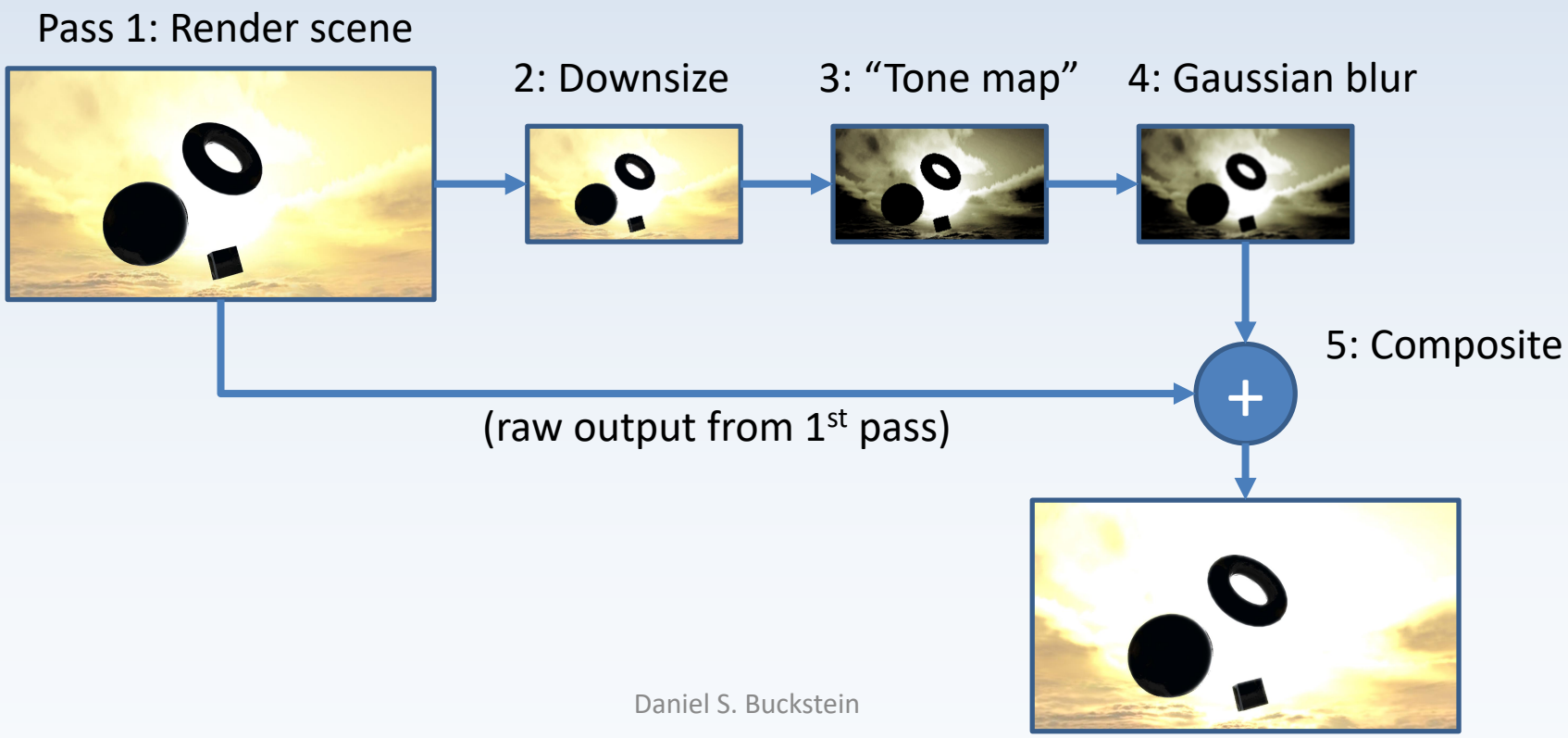
https://en.wikipedia.org/wiki/High-dynamic-range_imaging

HDRR: Bloom

- This process can be *simulated* in real-time rendering: ***High Dynamic Range Rendering***
- Multi-pass post-processing algorithm called "***Bloom***"
- "***The 4 B's***": a mnemonic by yours truly
  - Box
  - Bright
  - Blur
  - Blend

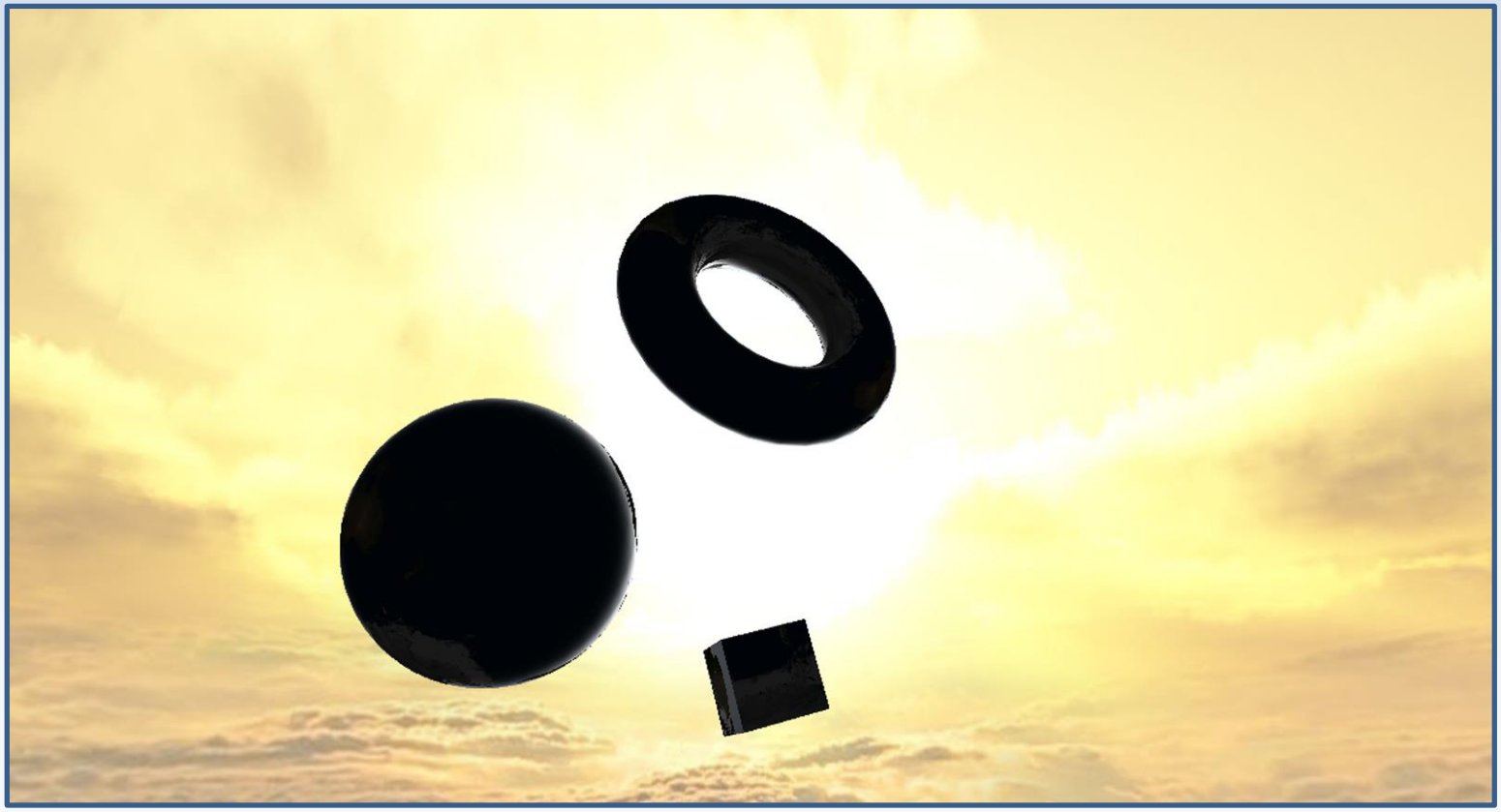
HDRR: Bloom

- ***Bloom*** shader network diagram:
  - Core algorithm



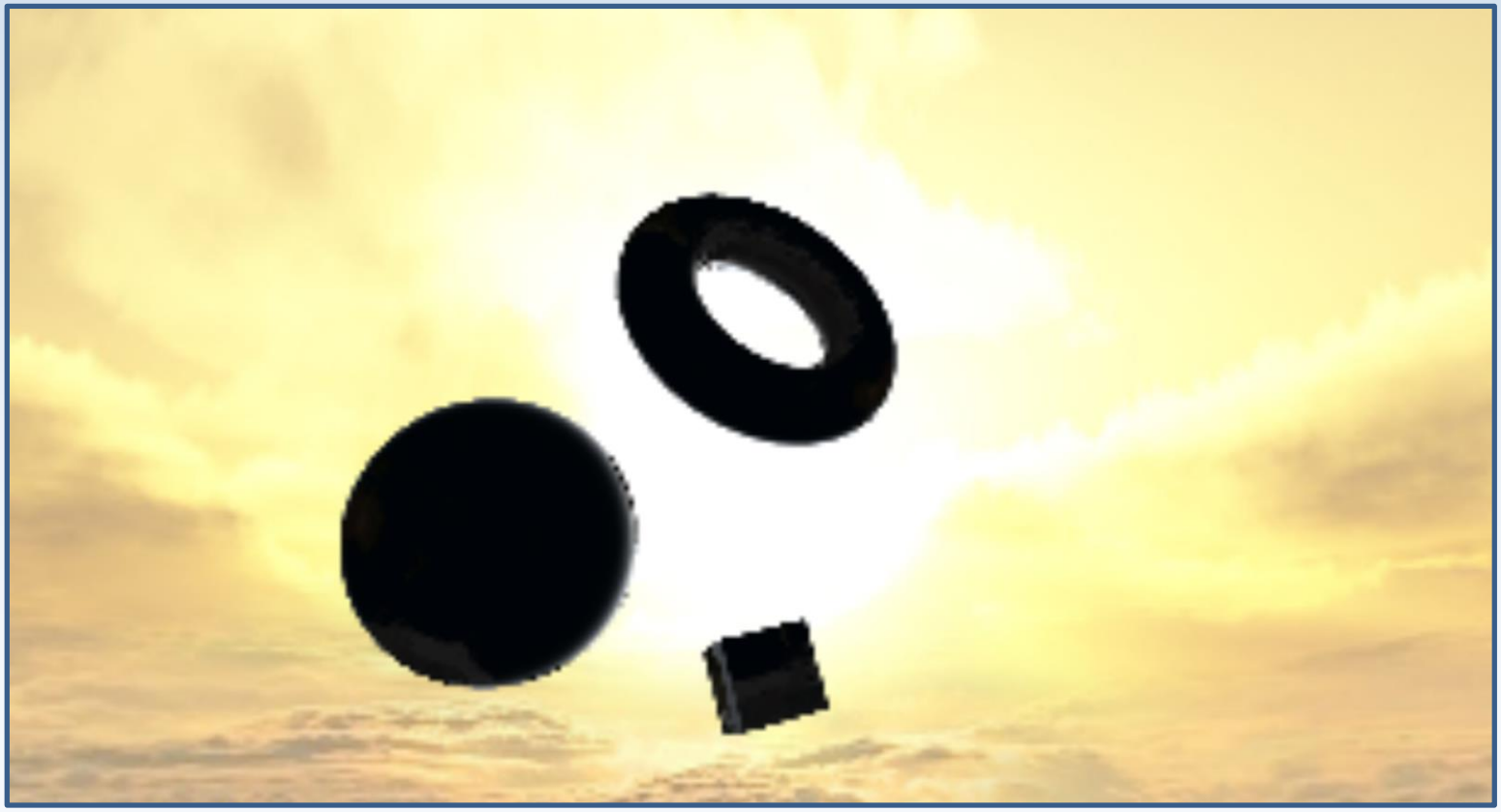
HDRR: Bloom

- 1st pass: Render the scene



HDRR: Bloom

- 2nd pass: Downsize… Free *box blur*, speed



HDRR: Bloom

- 3rd pass: Simulated tone mapping (bright pass)

HDRR: Bloom

- 3rd pass: Simulated tone mapping (bright pass)
- Complex: curve editor like Photoshop
- Simple: use your knowledge of basic algos:
- Good example: Which function do we know that *compresses* a range???
- …so what function would *expand* a range???

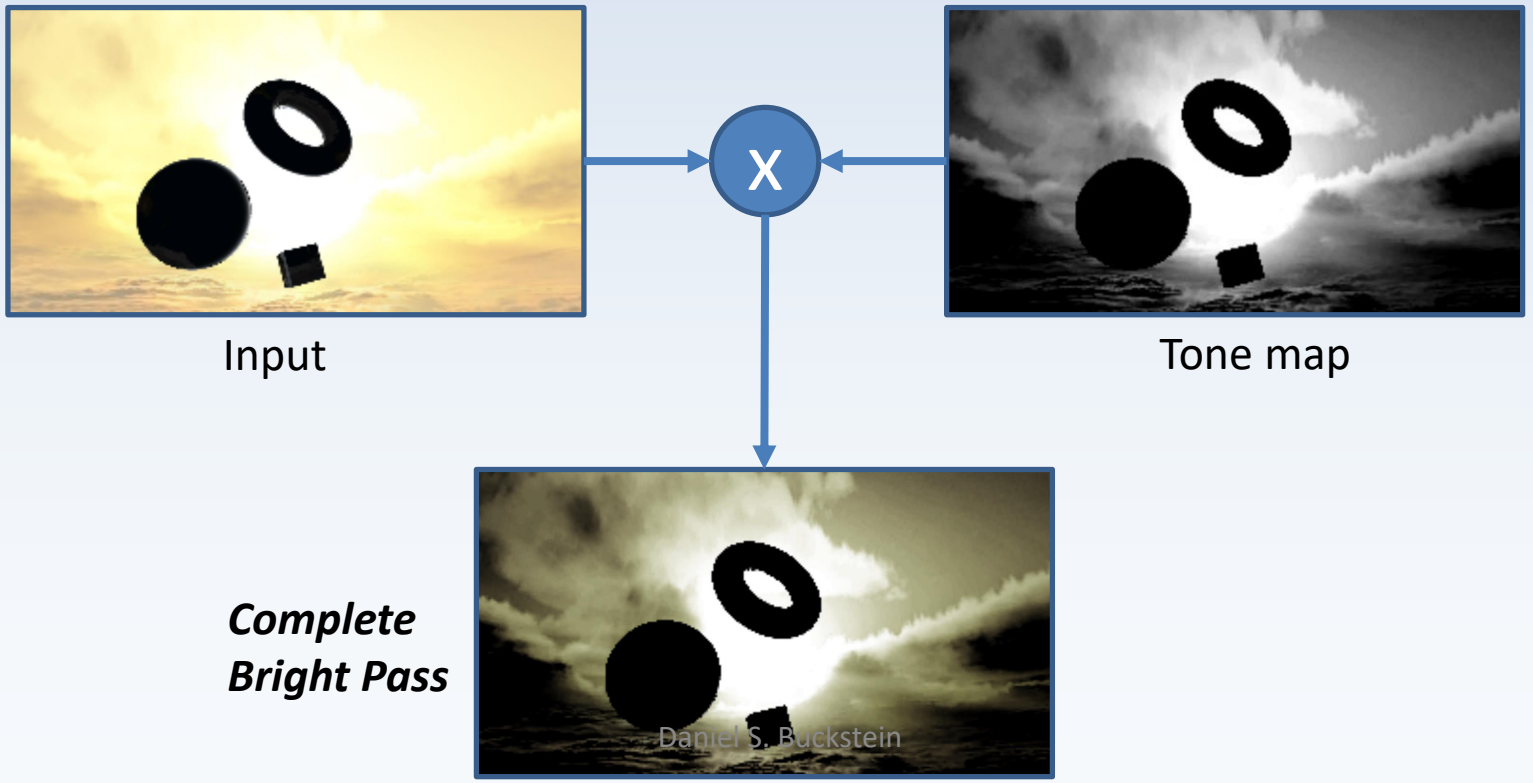
HDRR: Bloom

- 3rd pass: Simulated tone mapping (bright pass)
- Bright values are kept, dark values are tossed
- Calculate the *luminance* of each pixel and
- Run your bright pass function (e.g. deserialize)
    - The result of this step is called the ***tone map***

Input image | Luminance (L) | Bright = Deserialize(Deserialize(L))

HDRR: Bloom

- 3rd pass: Simulated tone mapping (bright pass)
- Multiply your ***tone map*** by the ***input image***



HDRR: Bloom

- 4th pass: Gaussian blurring

HDRR: Bloom

- 4th pass: Gaussian blurring
- The goal: bright areas ***flood over*** dark areas in the scene
- This is achieved using ***blurring***
- Blurring uses a ***convolution kernel***

HDRR: Bloom

- 4^{th} pass: Gaussian blurring
- 5x5 Gaussian blur kernel (normalized):

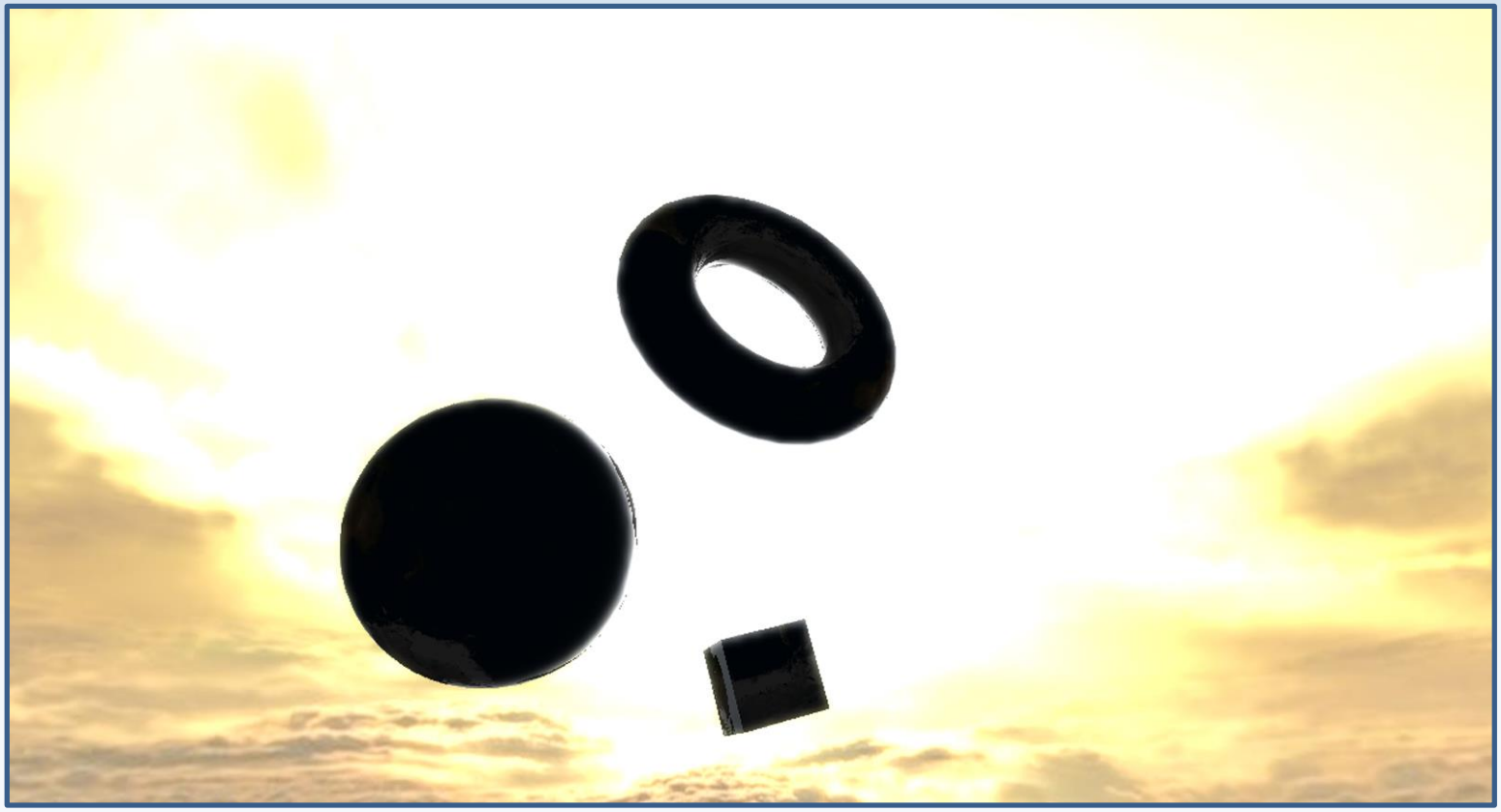
$$\frac{1}{256}\begin{bmatrix} 1 & 4 & 6 & 4 & 1 \\ 4 & 16 & 24 & 16 & 4 \\ 6 & 24 & 36 & 24 & 6 \\ 4 & 16 & 24 & 16 & 4 \\ 1 & 4 & 6 & 4 & 1 \end{bmatrix}$$

HDRR: Bloom

- 4th pass: Gaussian blurring
- Major problems with this???
- Nested for loops >__<
- …or 25 manual texture samples per pixel
- 7x7 kernel: 49 samples
- 9x9 kernel: 81 samples
- …terrible

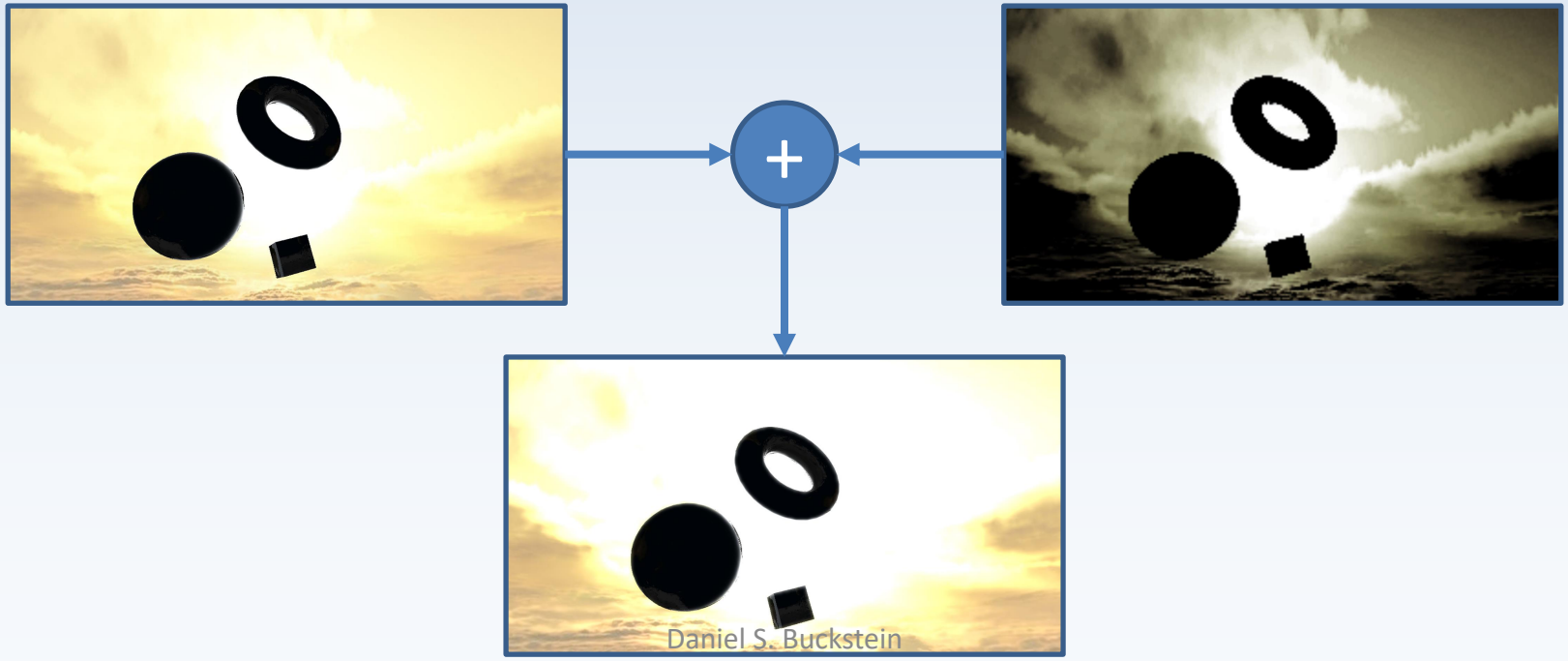
HDRR: Bloom

- 5th pass: Composite → “Bloom”



HDRR: Bloom

- 5th pass: Composite
- Fastest way to composite: ***additive***
- Original scene render + Gaussian pass



HDRR: Bloom

- For all passes:

```
// Demo.cpp: single pass draw routine
    ...
    fboList[currentPass].Activate();
    fboList[currentPass - 1].BindColour();
    programList[currentPass].Activate();
    DrawFSQ();
    ...
```

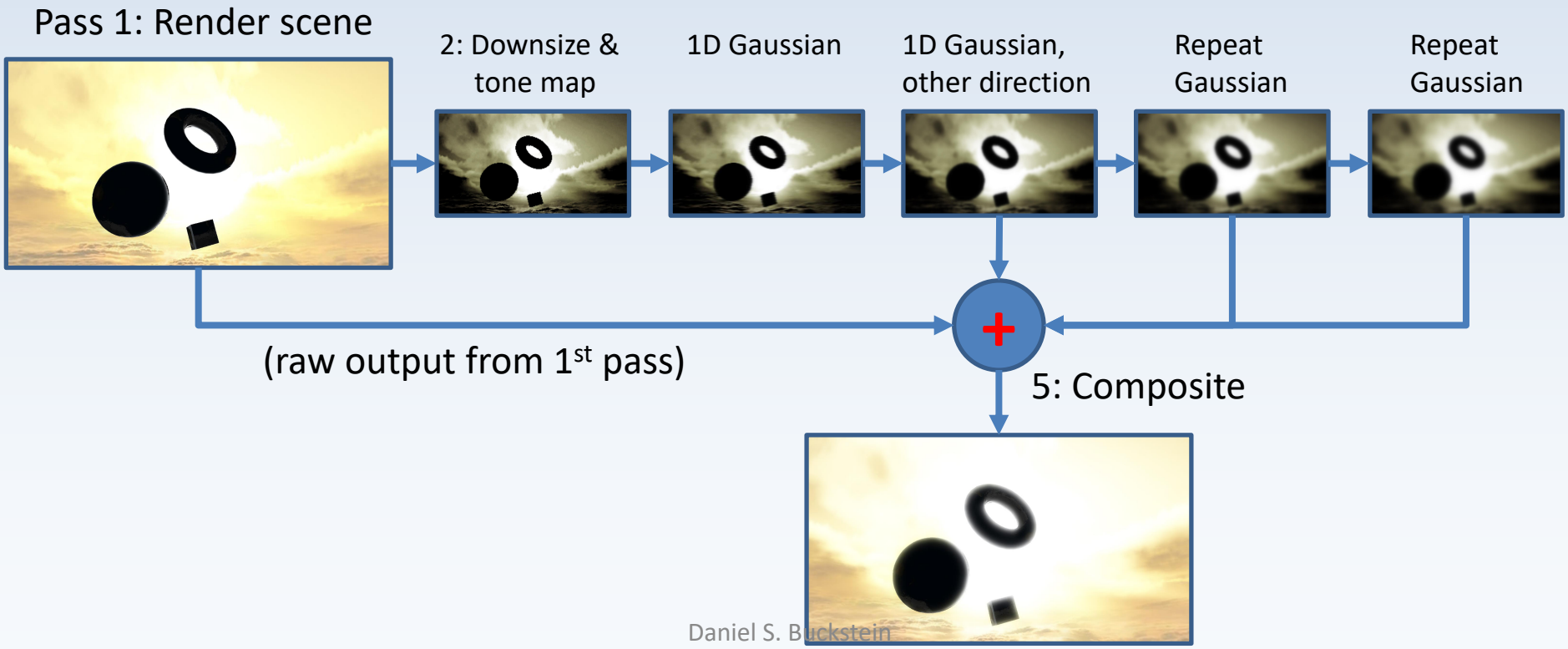
HDRR: Bloom

- For all passes:

```
// overall fragment shader structure:
    ...
varying vec2 texcoord;
uniform sampler2D inputTex;
    ...
    vec4 pix = texture2D(inputTex, texcoord);
    gl_FragColour = processPixel(pix);
```

Bloom Optimizations

- Optimizations and improvements… lots ☺
- Improved bloom shader network diagram:



Bloom Optimizations

- First optimization (dead simple):
- Bright pass and downscale happen at the same time
- The result is identical to doing them separately
- Immediately cuts an entire pass.
- The end.

Bloom Optimizations

- Second optimization: separate Gaussian blur into two 1D passes
- 5x5, 2D Gaussian blur convolution kernel:
- ..actually the product of ***two 1D kernels***:

$$G_{5\times5} = \frac{1}{256}\begin{bmatrix} 1 & 4 & 6 & 4 & 1 \\ 4 & 16 & 24 & 16 & 4 \\ 6 & 24 & 36 & 24 & 6 \\ 4 & 16 & 24 & 16 & 4 \\ 1 & 4 & 6 & 4 & 1 \end{bmatrix}$$

$$G_{5\times5} = G_{5\times1} * G_{1\times5}$$

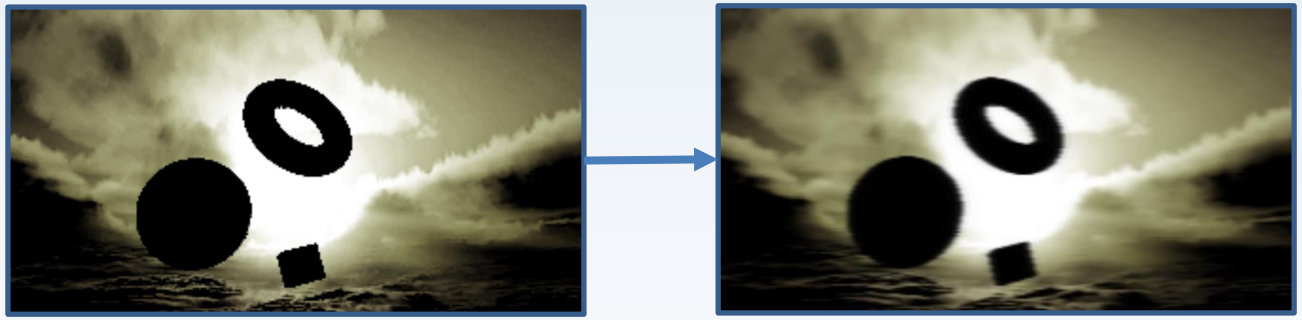
1D CONVOLUTION KERNELS!

$$= \frac{1}{16}\begin{bmatrix} 1 \\ 4 \\ 6 \\ 4 \\ 1 \end{bmatrix} * \frac{1}{16}\begin{bmatrix} 1 & 4 & 6 & 4 & 1 \end{bmatrix}$$

Bloom Optimizations

- Second optimization: separate Gaussian blur into two 1D passes
- Part 1: Horizontal Gaussian blur:
- ***Input*** is our tone mapped (bright-only) image
- ***Output*** is a horizontally-blurred image:

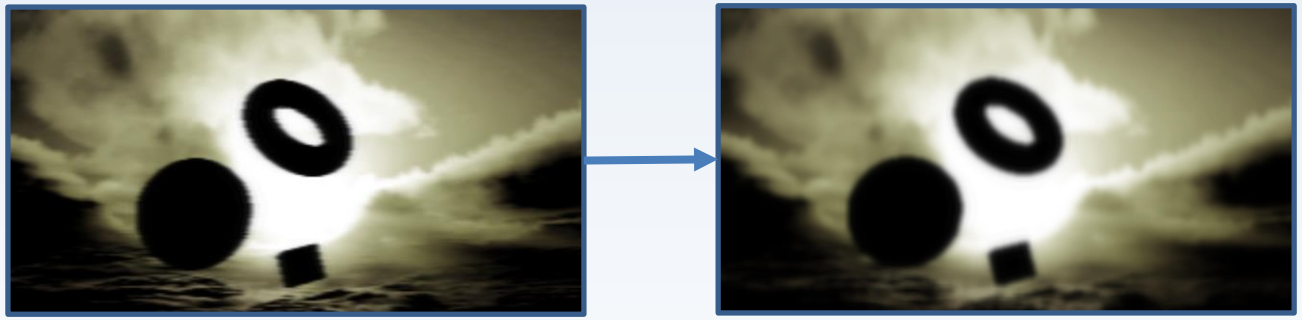
$$\frac{1}{16}[1 \quad 4 \quad 6 \quad 4 \quad 1] \ *$$



Bloom Optimizations

- Second optimization: separate Gaussian blur into two 1D passes
- Part 2: Vertical Gaussian blur:
- ***Input*** is our ***horizontal blur output!!!***
- ***Output*** is a *fully-blurred* image:

$$\frac{1}{16}\begin{bmatrix}1\\4\\6\\4\\1\end{bmatrix} * \quad$$



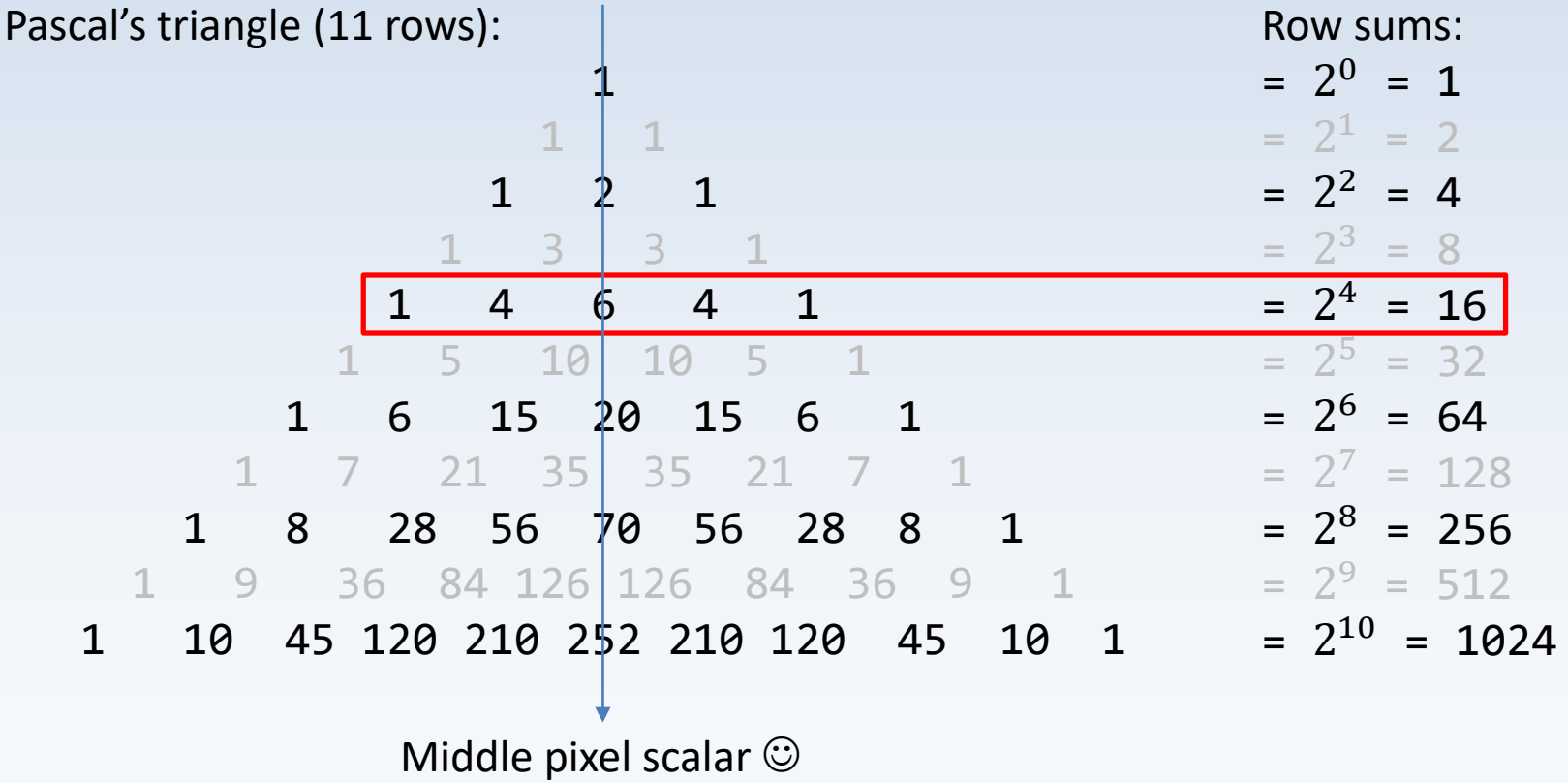
Bloom Optimizations

- Super pro tip: Where did these kernel values come from???

$$G_{5\times5} = \frac{1}{256}\begin{bmatrix}1 & 4 & 6 & 4 & 1\\ 4 & 16 & 24 & 16 & 4\\ 6 & 24 & 36 & 24 & 6\\ 4 & 16 & 24 & 16 & 4\\ 1 & 4 & 6 & 4 & 1\end{bmatrix} = \frac{1}{16}\begin{bmatrix}1\\4\\6\\4\\1\end{bmatrix} * \frac{1}{16}\begin{bmatrix}1 & 4 & 6 & 4 & 1\end{bmatrix}$$

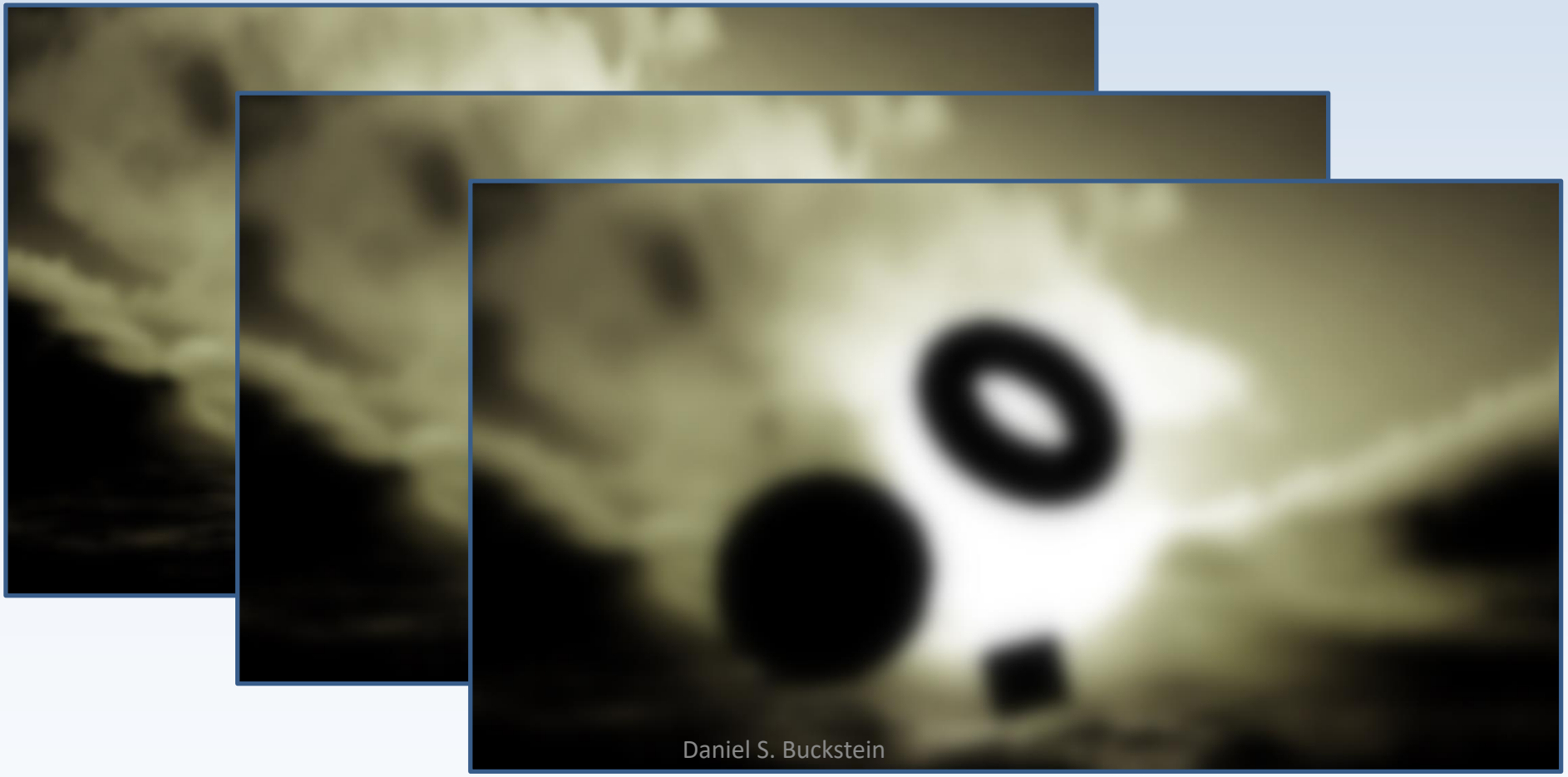
Bloom Optimizations

- …the *even-power* rows in ***Pascal's Triangle!***



Bloom Optimizations

- Third optimization: Repeat Gaussian blurring!



Bloom Optimizations

- Fourth optimization: Use a better compositing function ☺
- Additive is okay because it's easy…
- …but it can get too bright
- What other options does Photoshop offer?
- *Multiply*: product of images… problem?

Bloom Optimizations

- ***Screen*** function for compositing:
- We want to do what multiply does, but for brightness instead of darkness
- Solution???
- Invert inputs, multiply, invert result!

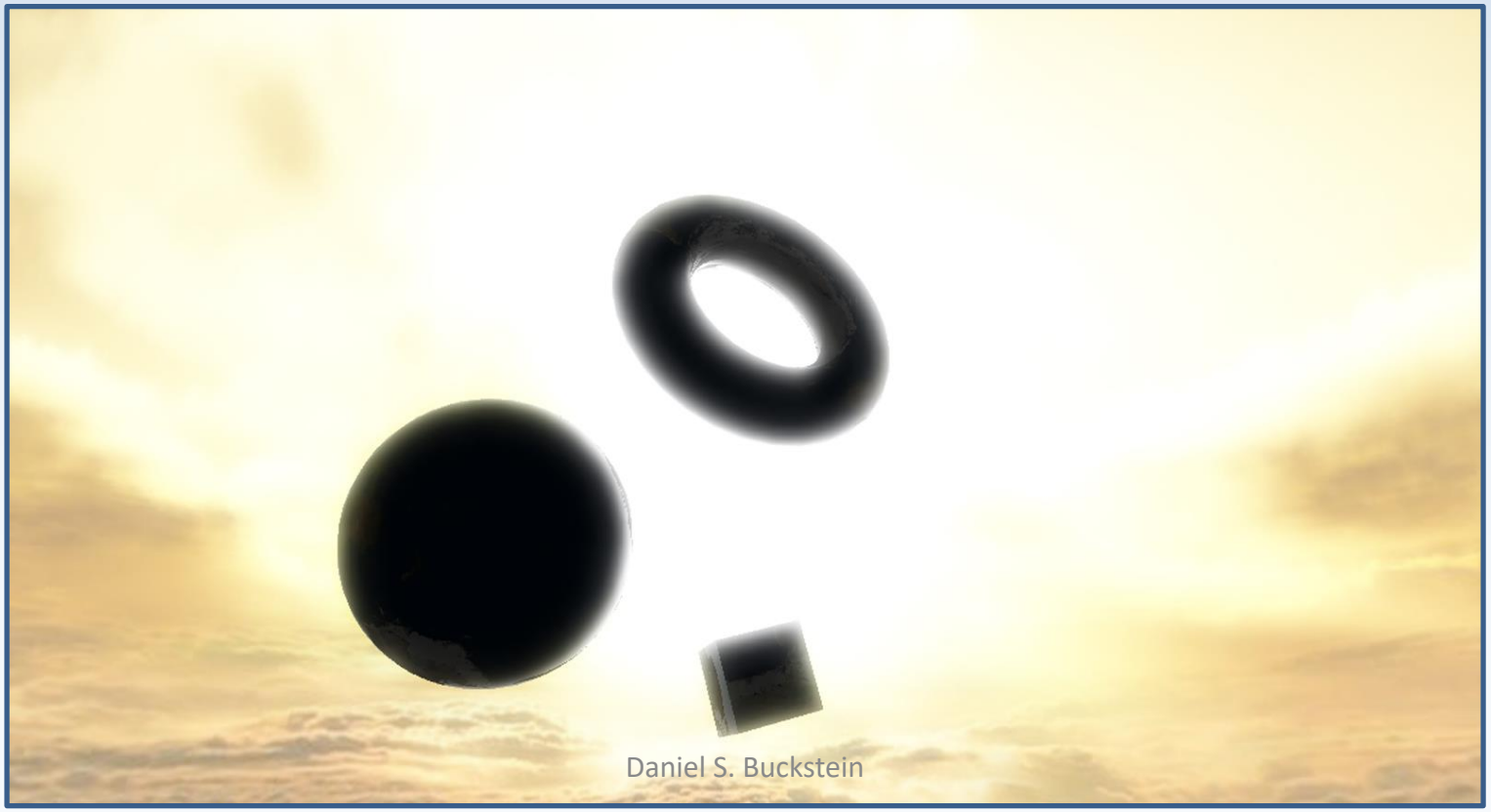
$$\text{screen}(A, B) = 1 - (1 - A)(1 - B)$$

- Same principle for more than 2 inputs:

$$\text{screen}(A, B, C, D) = 1 - (1 - A)(1 - B)(1 - C)(1 - D)$$

Bloom Optimizations

- Fifth optimization: For better compositing, blend original scene with ***all*** blur pass results!



Bloom Optimizations

- Final optimization: True HDR requires a *dynamic* range of color, as opposed to a *fixed* range
- Problem with standard FBOs???

  0-1 color range
- Solution: *float* buffers can store values beyond 0-1 range!
- Use this information however you please ☺

The end.

- Questions? Comments? Concerns?