Optimizations for Rendering Realistic Lens flares in Polynomial Optics

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CS Department Talk

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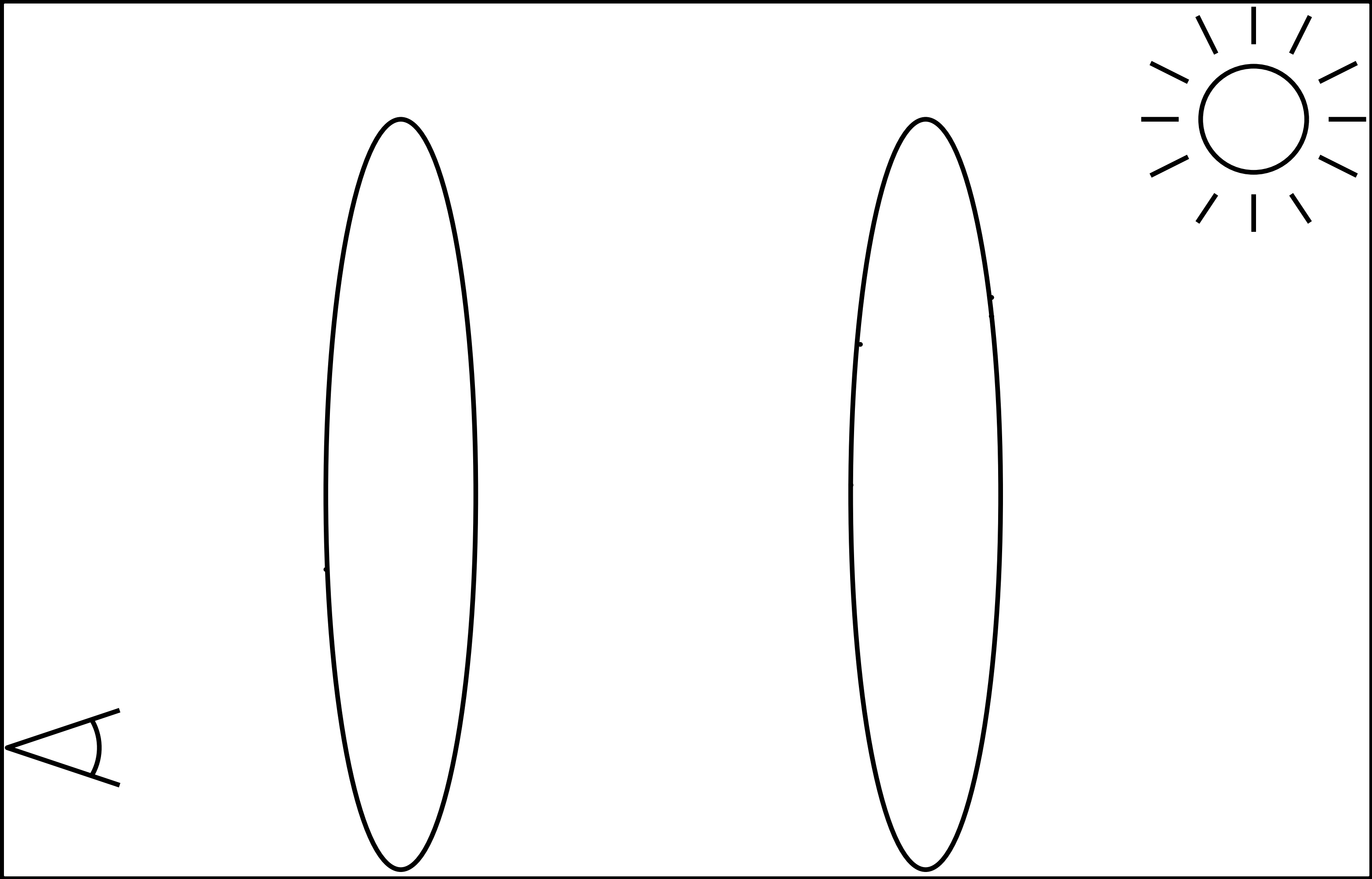
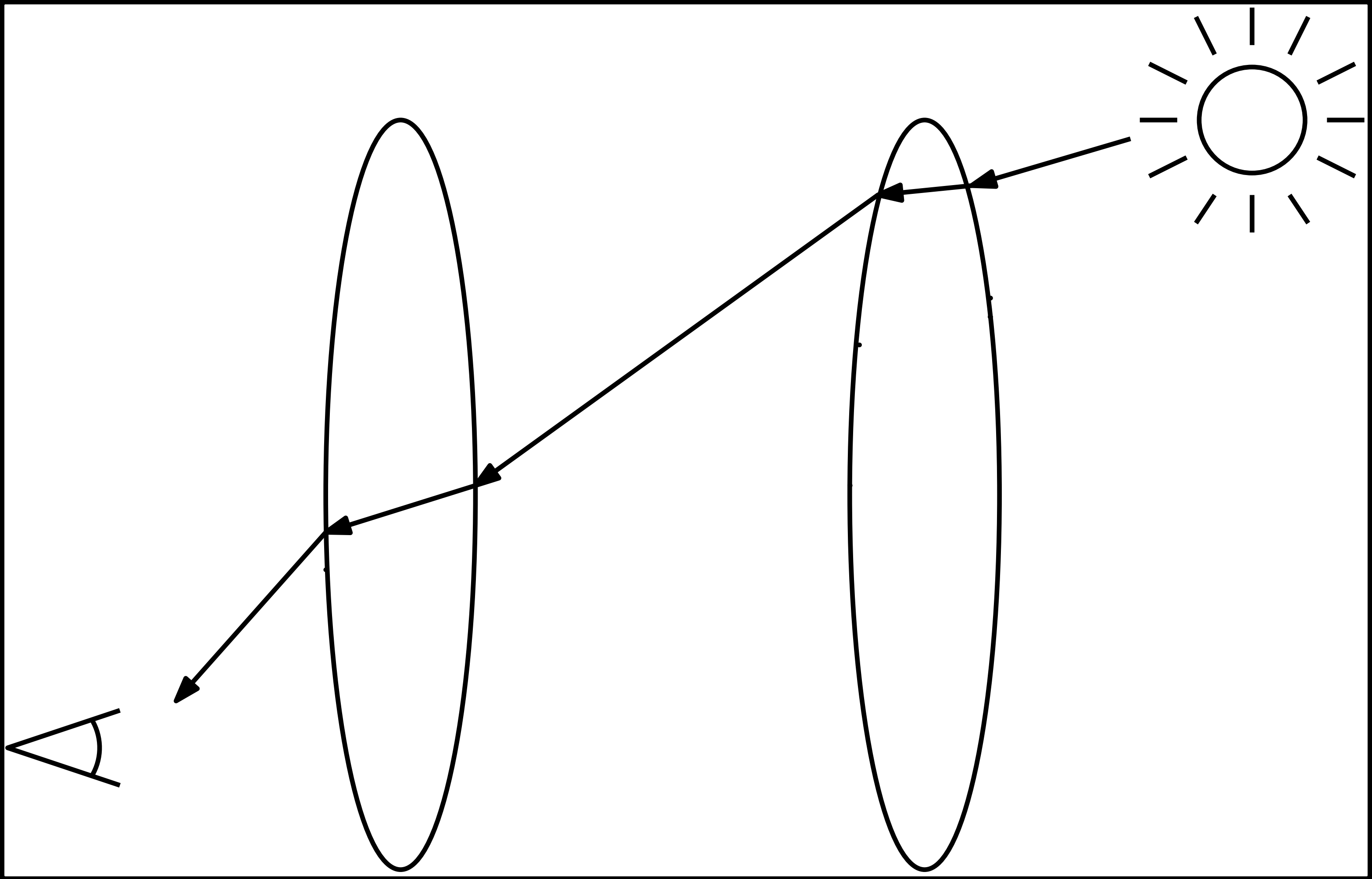
Lens Flare

Photo Credit: HWRG

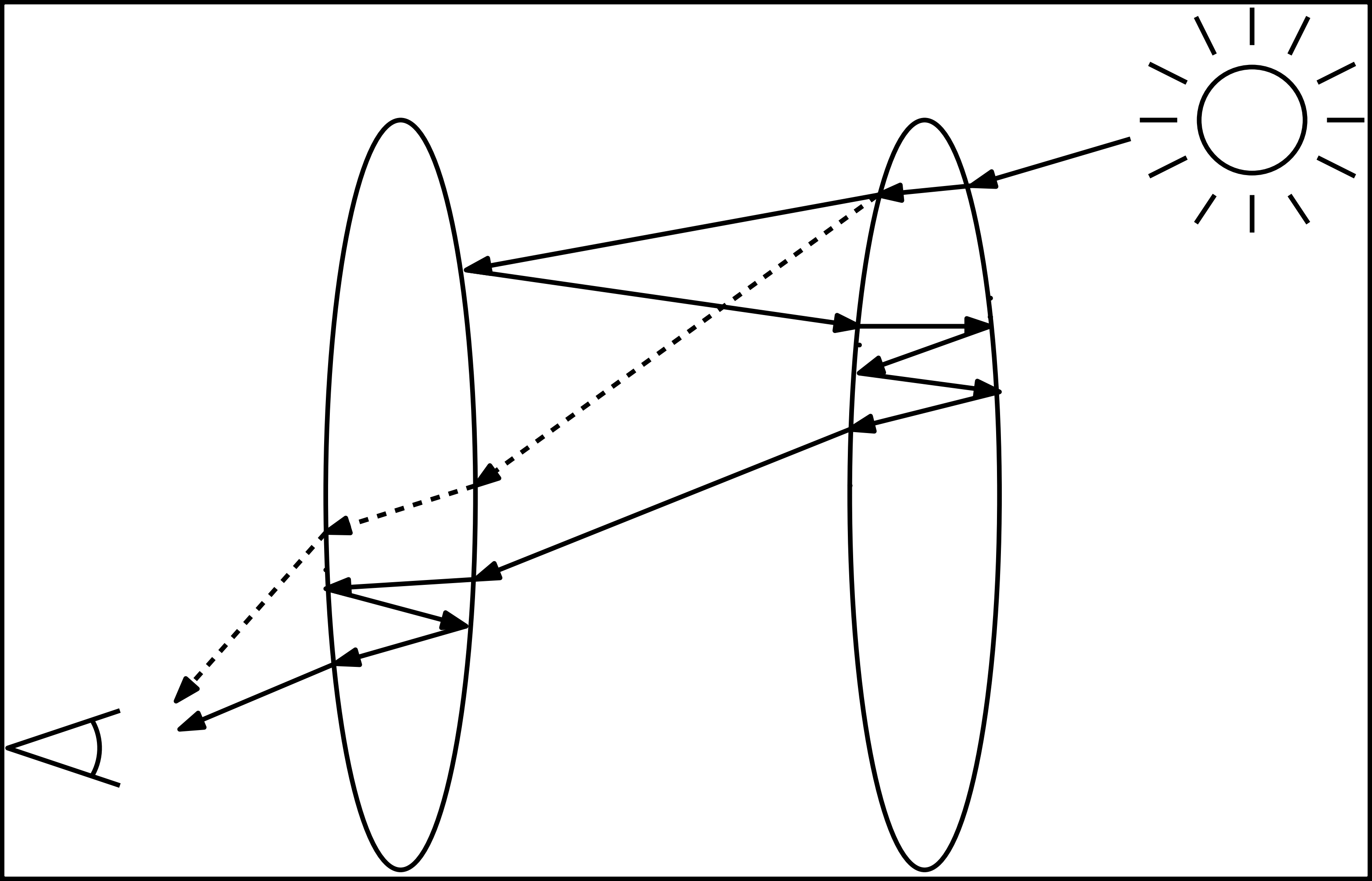
Lens Flare



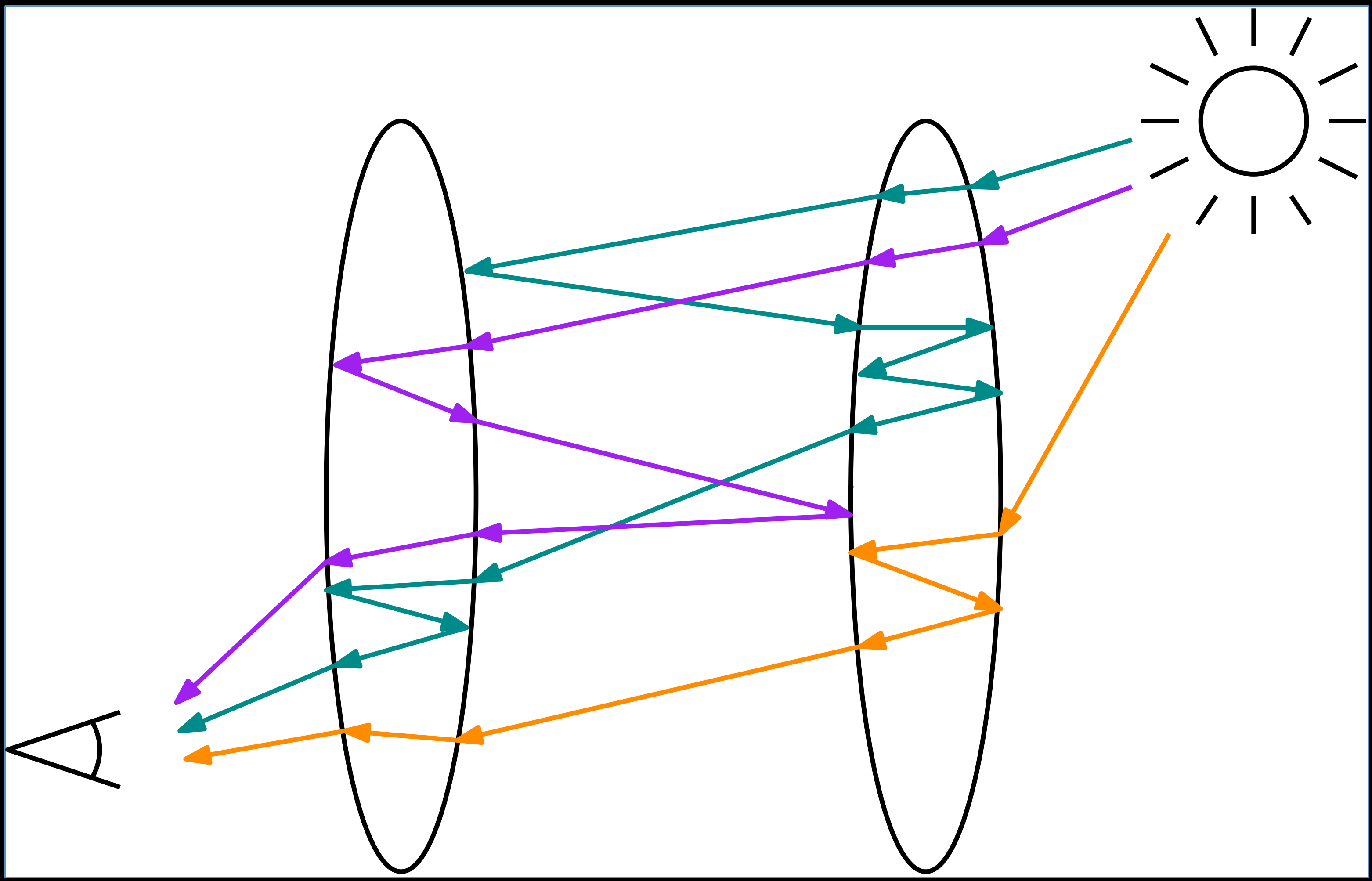
Lens Flare – In a Perfect World . . .



Lens Flare – Complex Paths

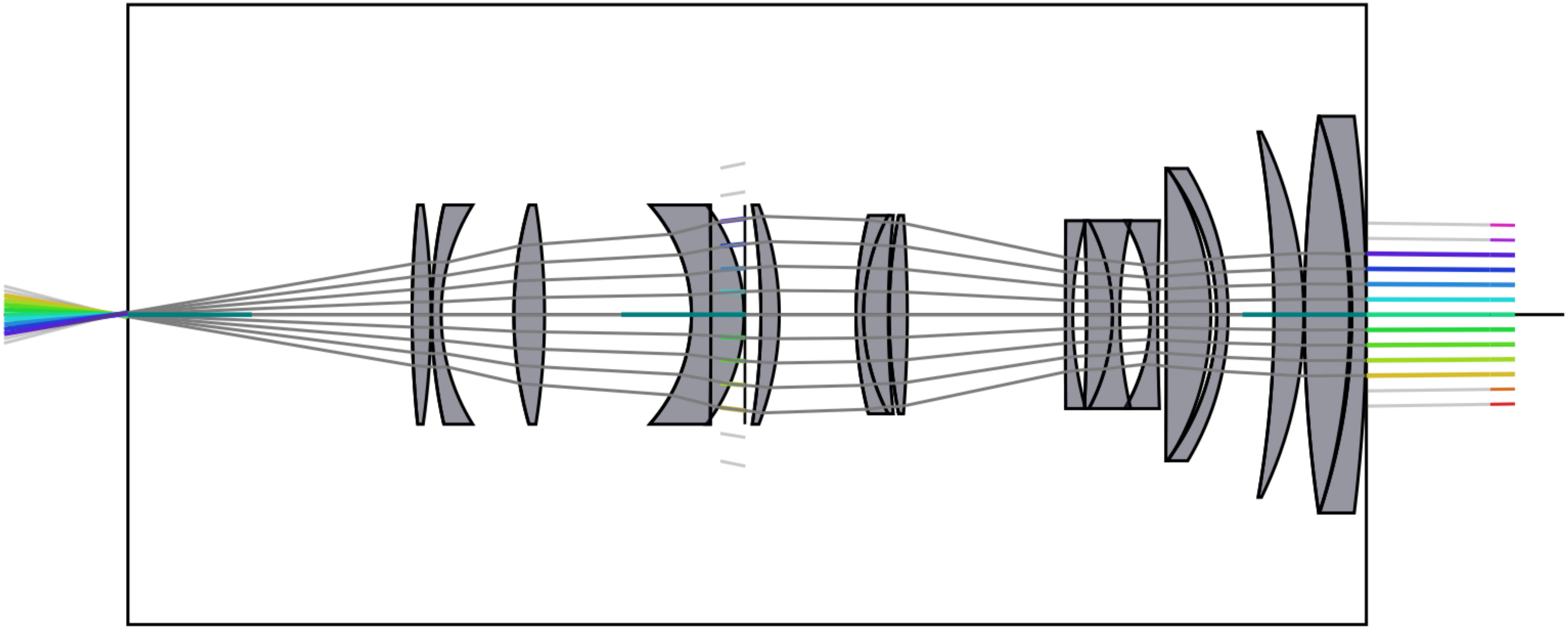


Lens Flare – Multiple Samples



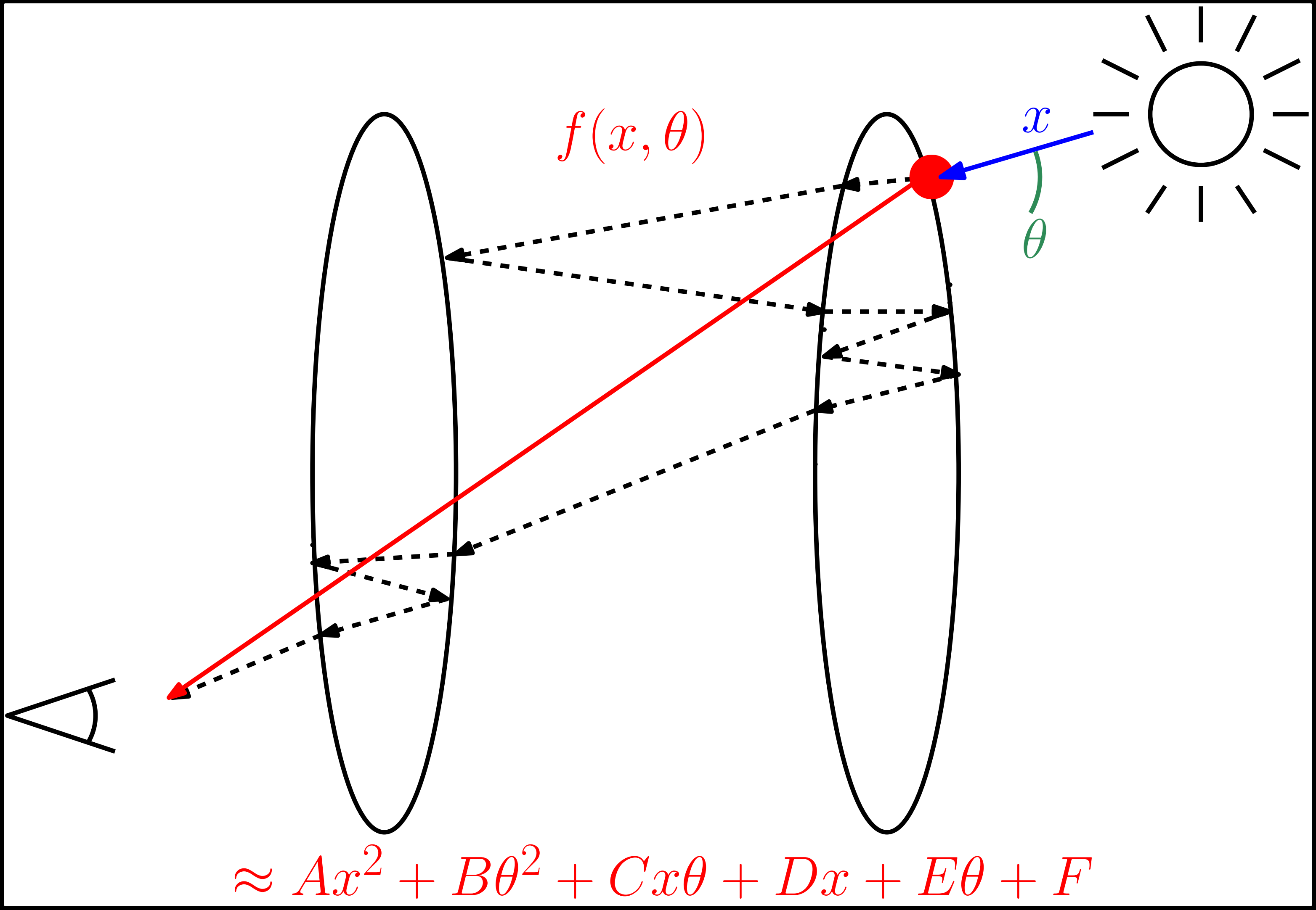
Lens Systems Are Complex

Canon Zoom



Johannes Hanika and Carsten Dachsbacher. Efficient Monte Carlo rendering with realistic lenses. Computer Graphics Forum (Proceedings of Eurographics), 33(2), April 2014.

Mapping Function



Mapping Function

```
x0'= 0.069134191*x1 + 0.00036023074*x1*x2 - 0.0001688411*x1*x2^2 + 3.2458257*E -
   7*x1*x2^3 - 9.2272451*E - 8*x1*x2^4 - 0.00016840819*x1^3 + 3.2458172*E -
   7*x1^3*x2 - 1.8454372*E - 7*x1^3*x2^2 - 9.2268486*E - 8*x1^5 - 7.3207025*E -
   6*x0 + 4.1412478*E - 9*x0*x2 - 1.0656848*E - 9*x0*x2^2 + 2.6268905*E -
   12*x0*x2^3 - 5.6287706*E - 13*x0*x2^4 - 3.1231979*E - 9*x0*x1^2 + 7.5700566*E
   - 12*x0*x1^2*x2 - 2.9830253*E - 12*x0*x1^2*x2^2 - 2.4200917*E - 12*x0*x1^4 -
   3.8649941*E - 14*x0^2*x1 + 6.0552599*E - 17*x0^2*x1*x2 - 2.5149545*E -
   17*x0^2*x1*x2^2 - 3.9291562*E - 17*x0^2*x1^3 + 2.2452928*E - 20*x0^3 +
   9.3615152*E - 23*x0^3*x2 - 3.570534*E - 23*x0^3*x2^2 - 2.6169659*E -
   22*x0^3*x1^2 - 4.3705215*E - 28*x0^4*x1 - 6.140602*E - 34*x0^5
x1'= 1.2794179 + 0.068410441*x2 + 0.00054647529*x2^2 - 0.00016929924*x2^3 +
   4.2295244*E - 7*x2^4 - 9.2268486*E - 8*x2^5 + 0.00018560429*x1^2 -
   0.0001688676*x1^2*x2 + 5.2132975*E - 7*x1^2*x2^2 - 1.8454072*E - 7*x1^2*x2^3 +
   9.8373164*E - 8*x1^4 - 9.2272437*E - 8*x1^4*x2 + 4.1412287*E - 9*x0*x1 -
   2.0685693*E - 9*x0*x1*x2 + 7.5700566*E - 12*x0*x1*x2^2 - 1.8572524*E -
   12*x0*x1*x2^3 + 2.6268844*E - 12*x0*x1^3 - 1.8572429*E - 12*x0*x1^3*x2 -
   3.9239987*E - 15*x0^2 - 1.4970528*E - 14*x0^2*x2 + 2.4679362*E - 17*x0^2*x2^2 -
   1.0118632*E - 17*x0^2*x2^3 + 2.7296609*E - 17*x0^2*x1^2 - 2.4260539*E -
   17*x0^2*x1^2*x2 + 9.3615506*E - 23*x0^3*x1 - 1.0550567*E - 22*x0^3*x1*x2 +
   1.0732069*E - 28*x0^4 + 9.8601372*E - 29*x0^4*x2
x2'= 0.0017209146 - 0.0022226868*x2 + 0.00071769056*x2^2 + 0.00071769056*x1^2 +
   1.2717995*E - 8*x0*x1 + 5.6343012*E - 14*x0^2
```

Problem

How do we best evaluate these polynomials?

Best refers to how quickly we evaluate the polynomials and which polynomials retain enough information to create images with high fidelity.

Two Approaches:

- Removing Terms
- Memoization

Removing Terms

```
x0'= 0.069134191*x1 + 0.00036023074*x1*x2 - 0.0001688411*x1*x2^2 + 3.2458257*E -
   7*x1*x2^3 - 9.2272451*E - 8*x1*x2^4 - 0.00016840819*x1^3 + 3.2458172*E -
   7*x1^3*x2 - 1.8454372*E - 7*x1^3*x2^2 - 9.2268486*E - 8*x1^5 - 7.3207025*E -
   6*x0 + 4.1412478*E - 9*x0*x2 - 1.0656848*E - 9*x0*x2^2 + 2.6268905*E -
   12*x0*x2^3 - 5.6287706*E - 13*x0*x2^4 - 3.1231979*E - 9*x0*x1^2 + 7.5700566*E
   - 12*x0*x1^2*x2 - 2.9830253*E - 12*x0*x1^2*x2^2 - 2.4200917*E - 12*x0*x1^4 -
   3.8649941*E - 14*x0^2*x1 + 6.0552599*E - 17*x0^2*x1*x2 - 2.5149545*E -
   17*x0^2*x1*x2^2 - 3.9291562*E - 17*x0^2*x1^3 + 2.2452928*E - 20*x0^3 +
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   0.0001688676*x1^2*x2 + 5.2132975*E - 7*x1^2*x2^2 - 1.8454072*E - 7*x1^2*x2^3 +
   9.8373164*E - 8*x1^4 - 9.2272437*E - 8*x1^4*x2 + 4.1412287*E - 9*x0*x1 -
   2.0685693*E - 9*x0*x1*x2 + 7.5700566*E - 12*x0*x1*x2^2 - 1.8572524*E -
   12*x0*x1*x2^3 + 2.6268844*E - 12*x0*x1^3 - 1.8572429*E - 12*x0*x1^3*x2 -
   3.9239987*E - 15*x0^2 - 1.4970528*E - 14*x0^2*x2 + 2.4679362*E - 17*x0^2*x2^2 -
   1.0118632*E - 17*x0^2*x2^3 + 2.7296609*E - 17*x0^2*x1^2 - 2.4260539*E -
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Removing Terms

```
x0'= 0.069134191*x1 + 0.00036023074*x1*x2 - 0.0001688411*x1*x2^2 + 3.2458257*E -
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   9.8373164*E - 8*x1^4 - 9.2272437*E - 8*x1^4*x2 + 4.1412287*E - 9*x0*x1 -
   2.0685693*E - 9*x0*x1*x2 + 7.5700566*E - 12*x0*x1*x2^2 - 1.8572524*E -
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   3.9239987*E - 15*x0^2 - 1.4970528*E - 14*x0^2*x2 + 2.4679362*E - 17*x0^2*x2^2 -
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   1.2717995*E - 8*x0*x1 + 5.6343012*E - 14*x0^2
```

Memoization

Let x = 3
and y = 4

x	x^2	x^3	x^4	x^5

y	y^2	y^3	y^4	y^5

Memoization

Let $x = 3$
and $y = 4$

x	x^2	x^3	x^4	x^5
3	9	27	81	243

y	y^2	y^3	y^4	y^5
4	16	64	256	1024

Memoization

Let $x = 3$
and $y = 4$

x	x^2	x^3	x^4	x^5
3	9	27	81	243

y	y^2	y^3	y^4	y^5
4	16	64	256	1024

$$Z = x + x^2 + x^2 + y^3 + x^4 + y^5 + y^5$$

Memoization

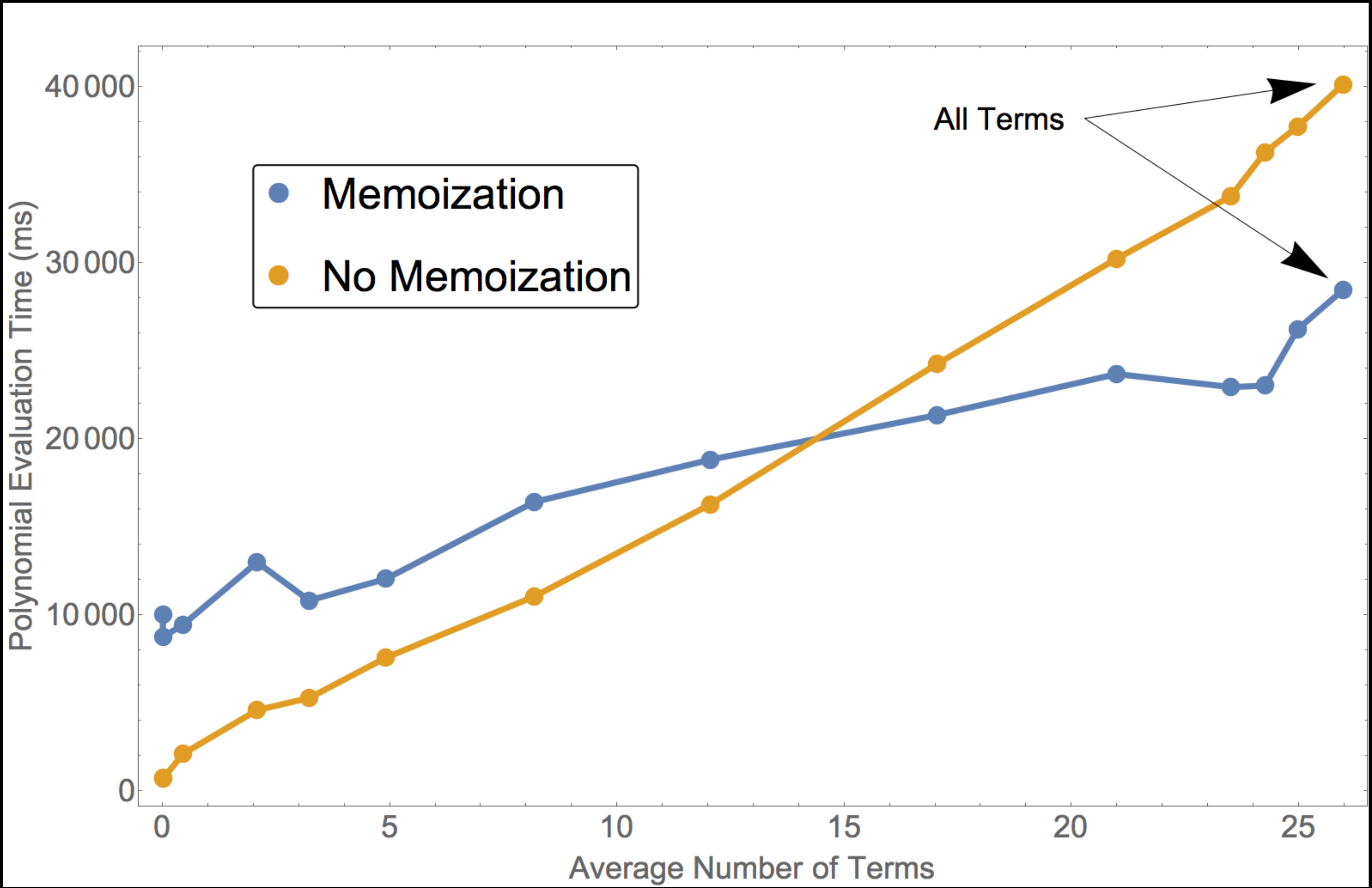
Let $x = 3$
and $y = 4$

x	x^2	x^3	x^4	x^5
3	9	27	81	243

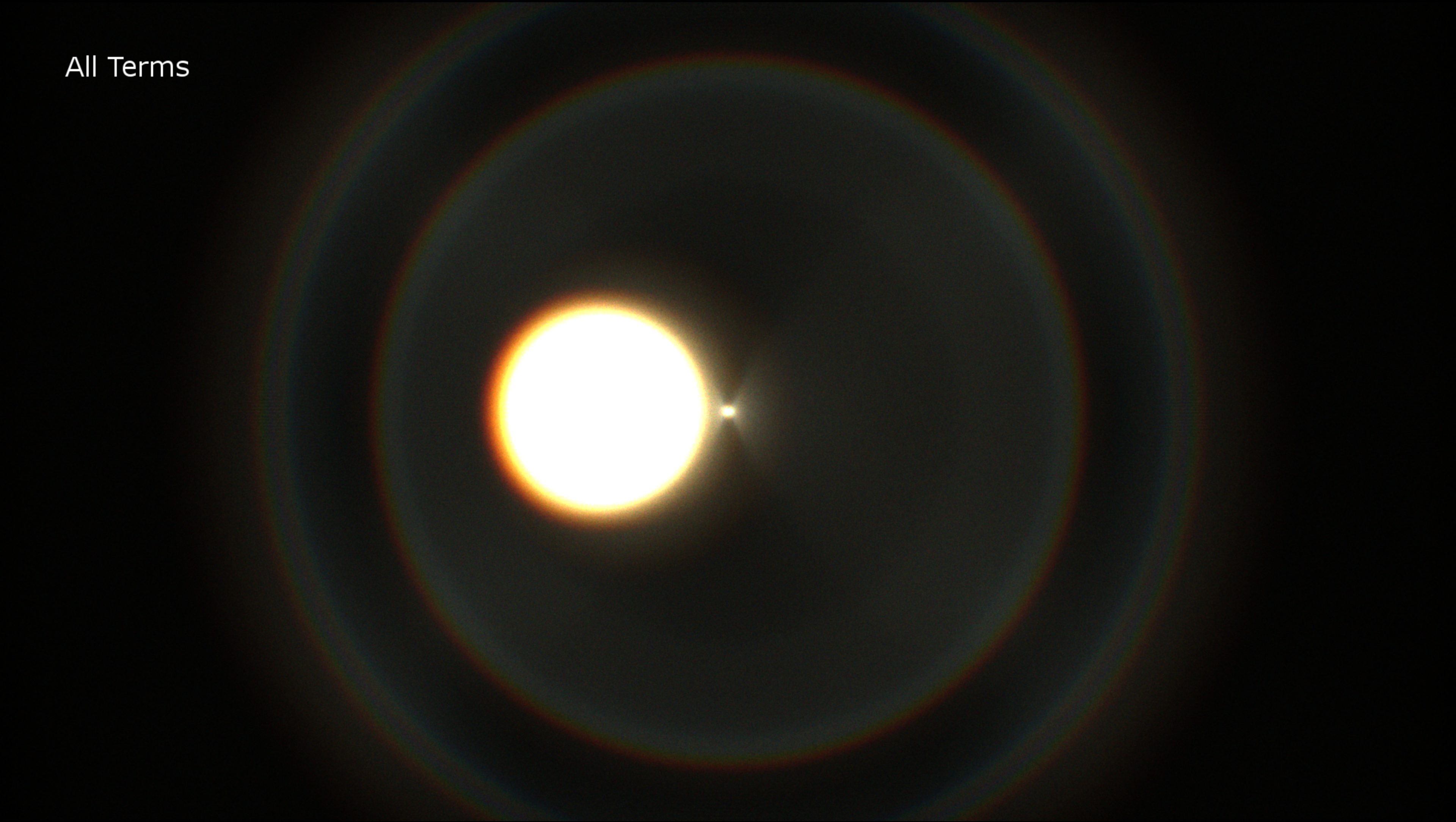
y	y^2	y^3	y^4	y^5
4	16	64	256	1024

$$Z = x + x^2 + x^2 + y^3 + x^4 + y^5 + y^5$$

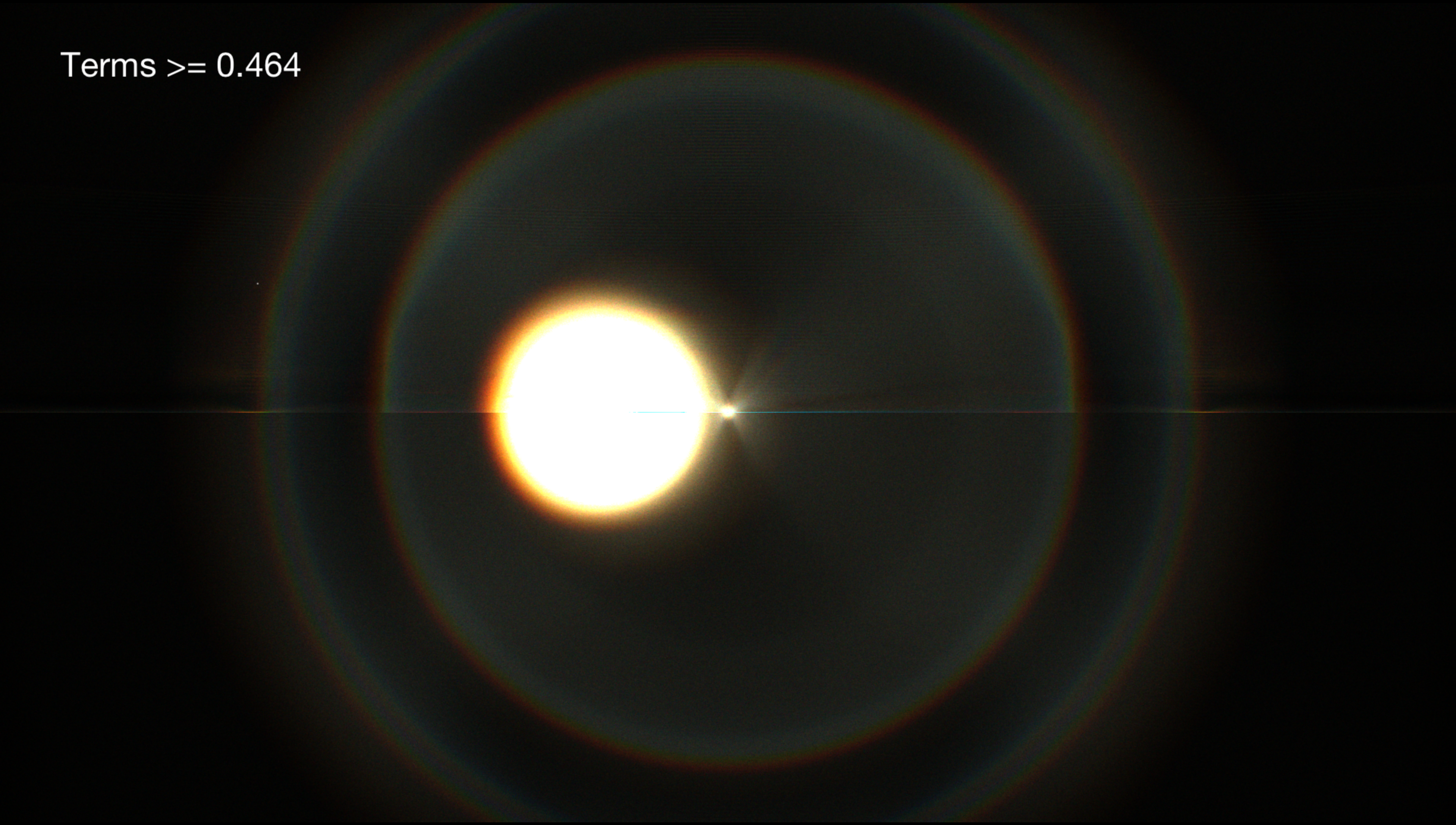
Memoization



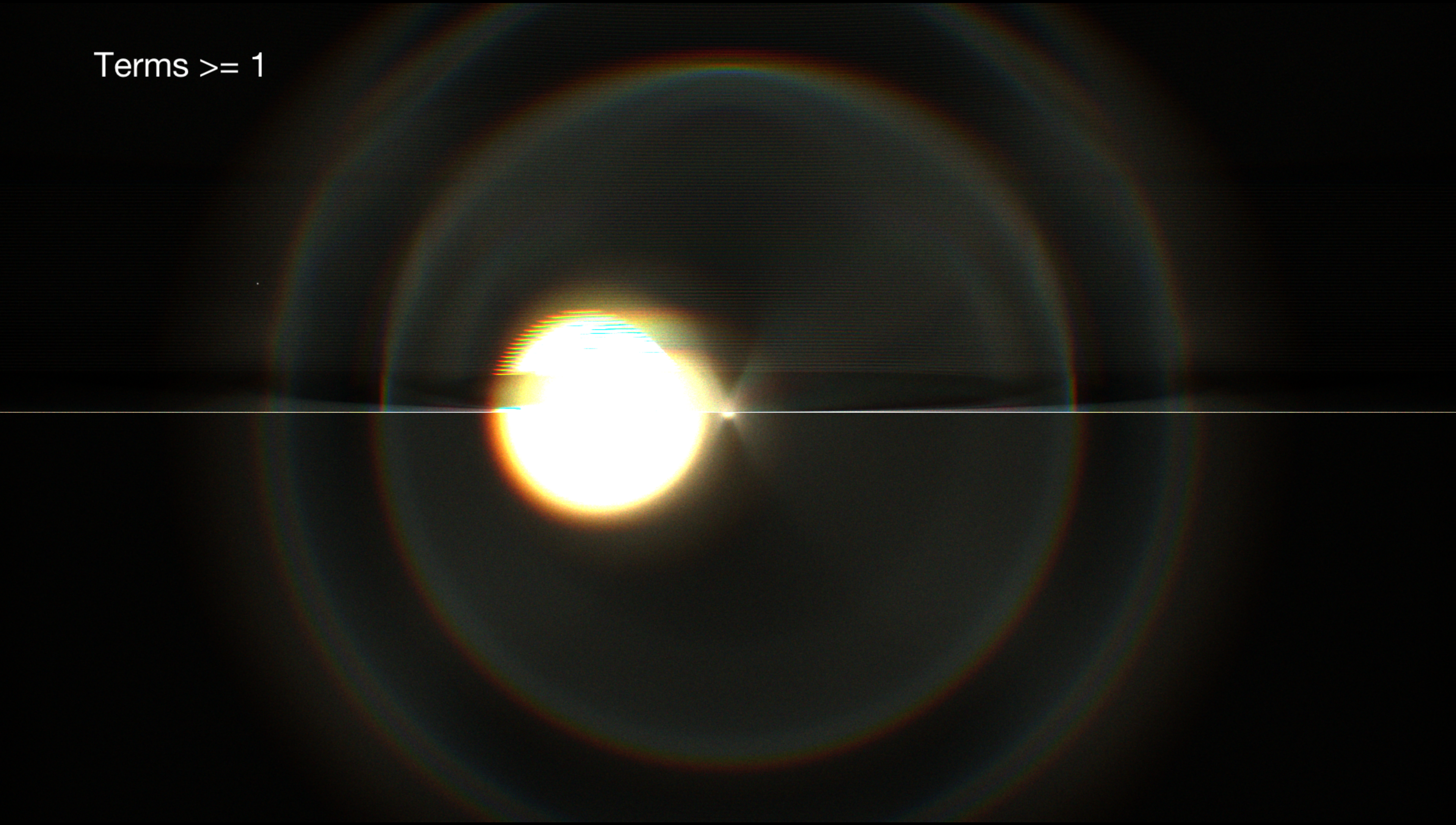
Produced Images



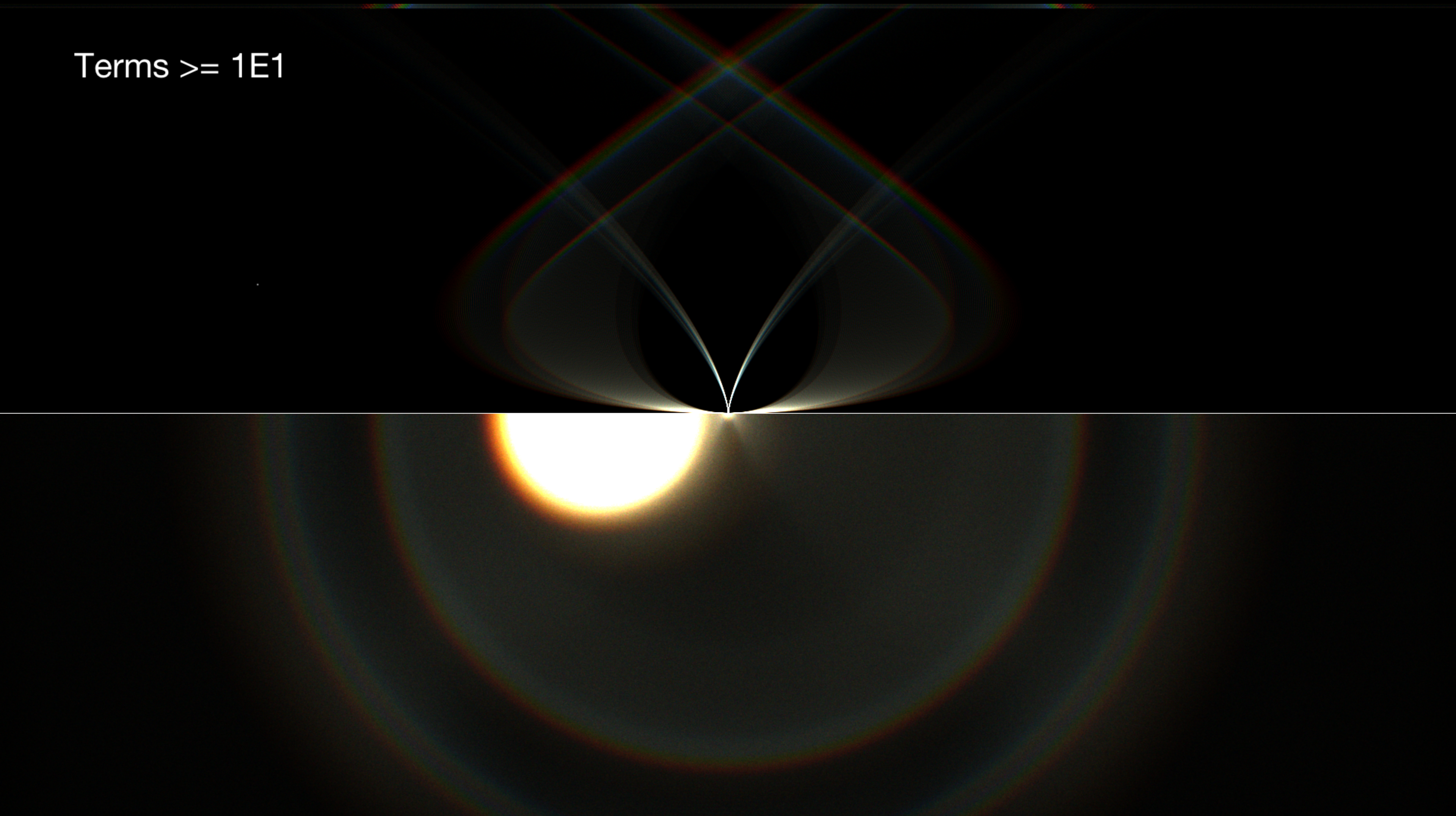
Produced Images



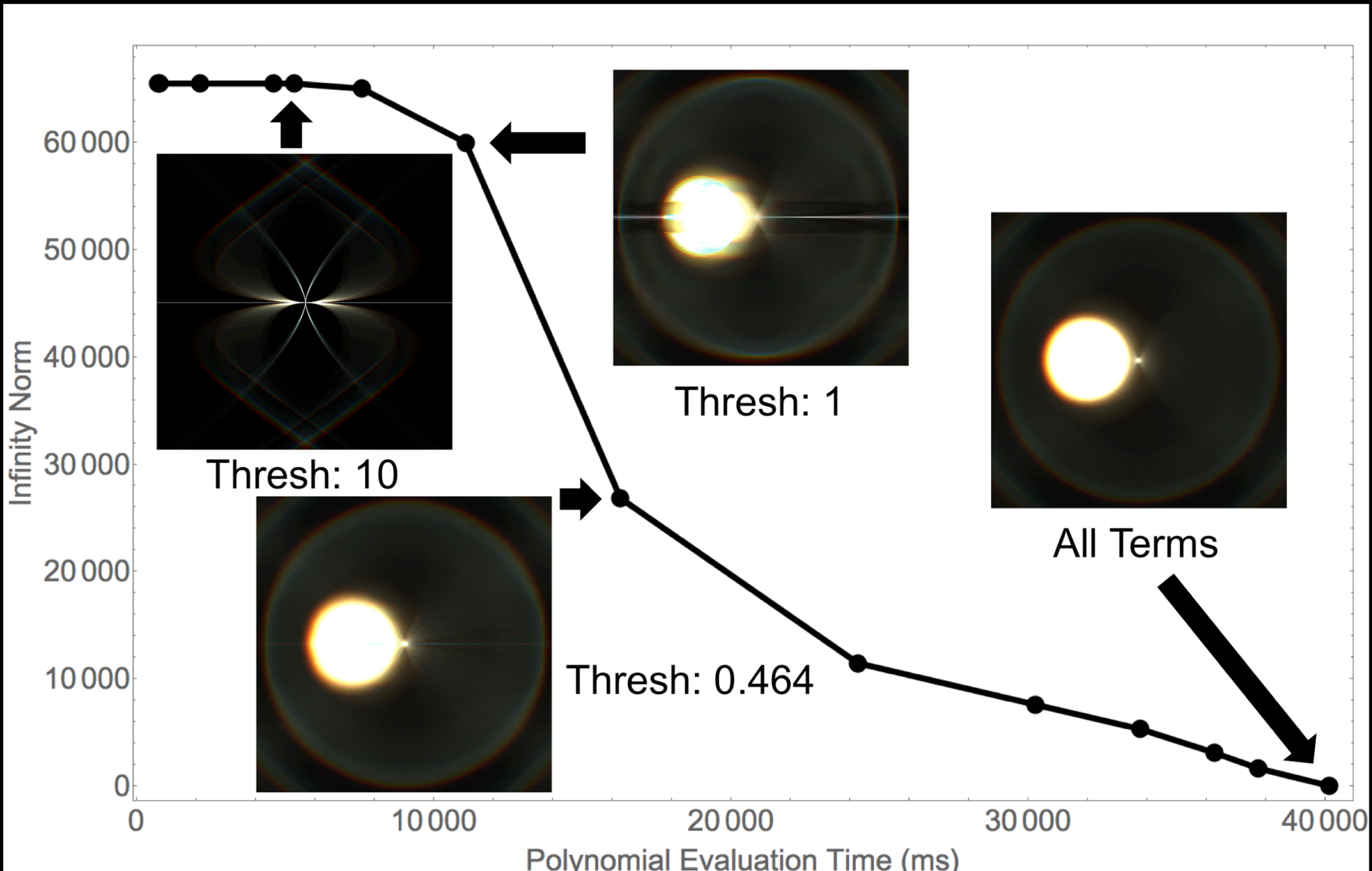
Produced Images



Produced Images



Evaluation



Infinity Norm
Polynomial Evaluation Time (ms)
0
10 000
20 000
30 000
40 000
50 000
60 000
0
10 000
20 000
30 000
40 000
Thresh: 10
Thresh: 1
Thresh: 0.464
All Terms

Summary

- Lens flares are hard to compute!
  - Can make improvements by dropping terms and memoizing data

Future Work

- Adjust coefficients in the polynomial to better meet a ground truth image.
  - See if we can recover images that look like a lens flare but are not exact.

Other Efforts

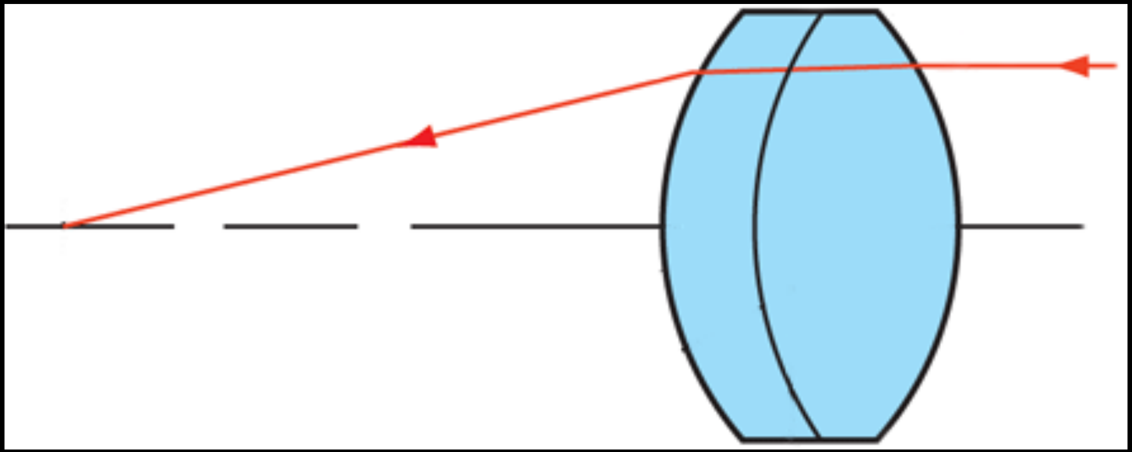
- Fixed exponentiation implementation
- Removed terms just by their coefficients
- Horner's method

$$-19 + 7x - 4x^2 + 6x^3$$

$$\Downarrow$$

$$((((0)x + 6)x - 4)x + 7)x - 19$$

Experimental Setup



- Degree 3 polynomials
- Achromatic Lens System
- Paths consisting of 2 and 4 reflections
- Using Polynomial Optics Library

"Why Use an Achromatic Lens?" Edmund Optics. Edmund Optics Inc., 2014. Web. 3 May 2015.