



# Voxel Cone Tracing and Sparse Voxel Octree for Real-time Global Illumination

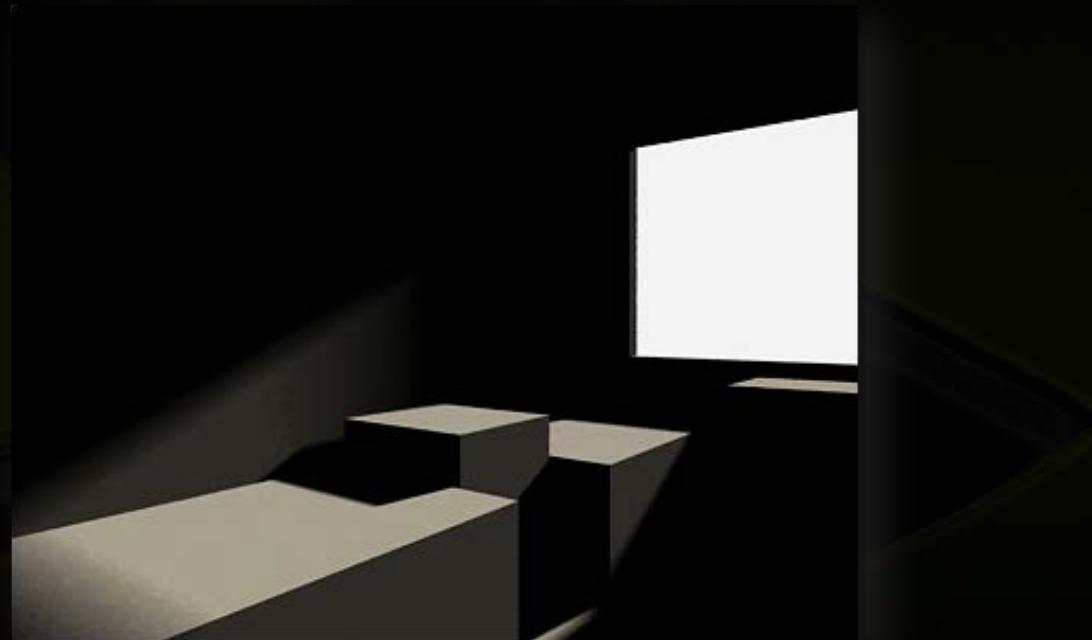
Cyril Crassin  
NVIDIA Research



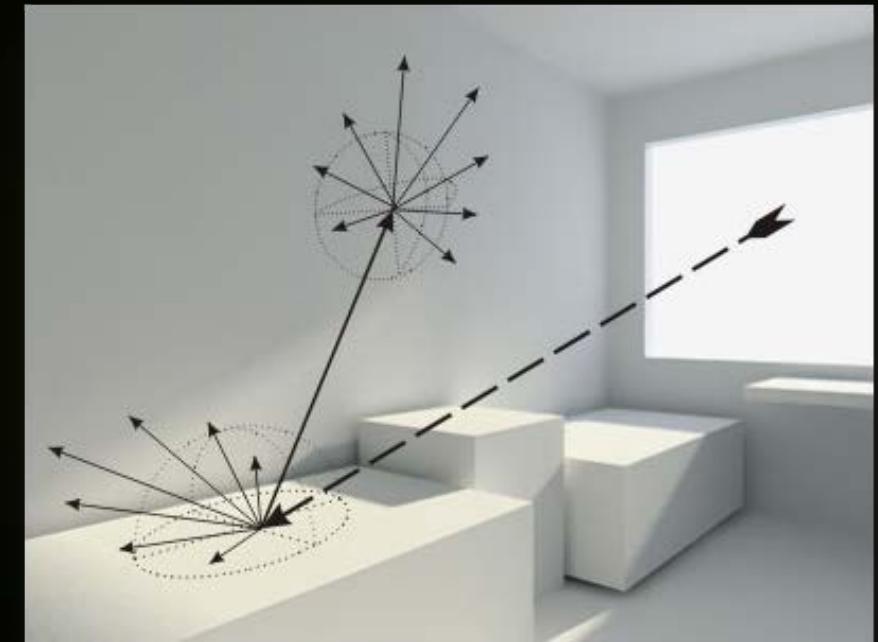
# Global Illumination



- Indirect effects
- Important for realistic image synthesis



Direct lighting



Direct+Indirect lighting

Settings:

Off

# Voxel-Based GI

8ms @ 512x512 - 27ms @ 720p - 62ms @ 1080p



# Voxel-based GI

- It can run in a game !
  - EPIC Games : SVogi





**DEMO**



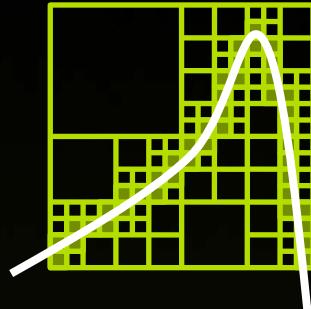
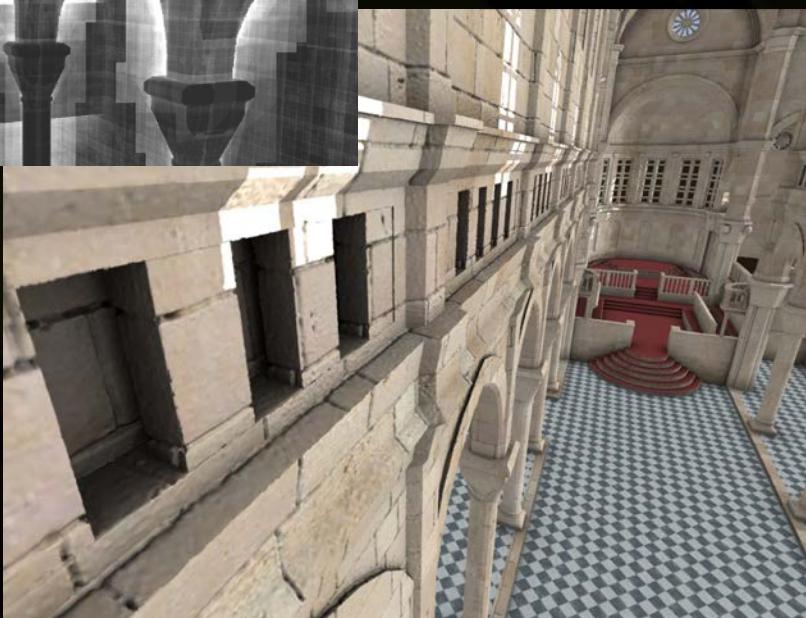
# Sparse Voxel Octree



- Detailed geometry rendering
  - Structured LODs



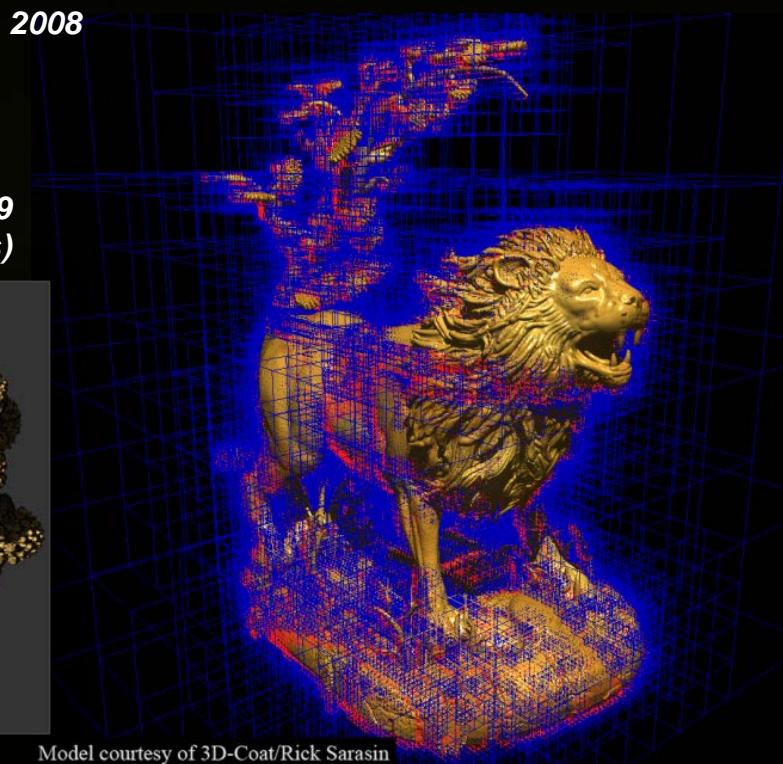
*Laine and Karras (NVIDIA)  
2010*



*Crassin et al. 2009  
(GigaVoxels)*



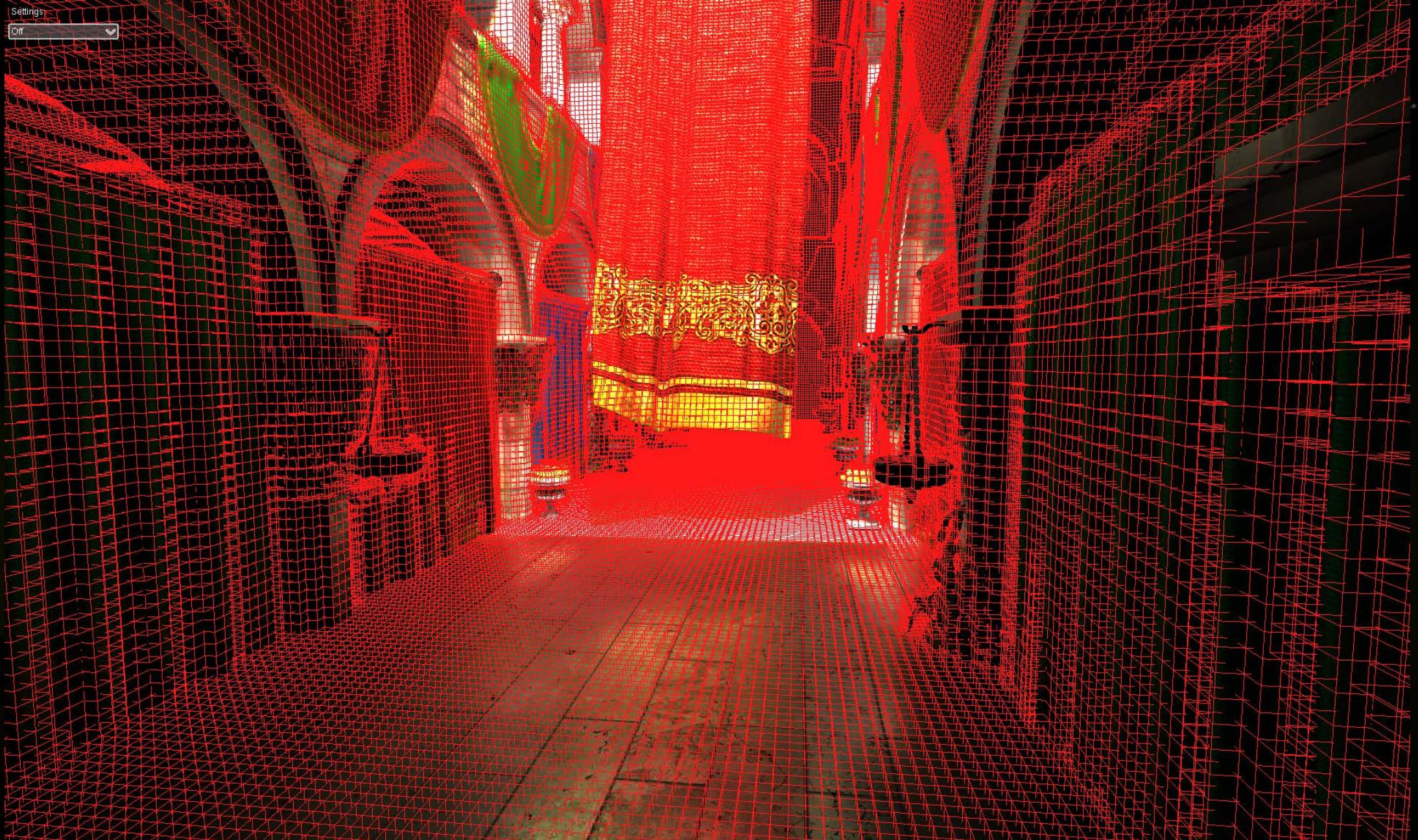
*Olick. 2008*



Model courtesy of 3D-Coat/Rick Sarasin

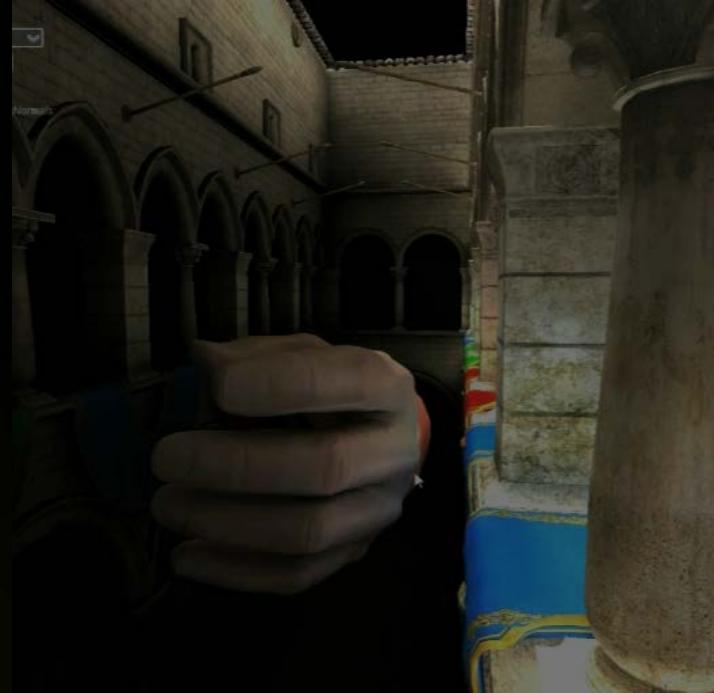
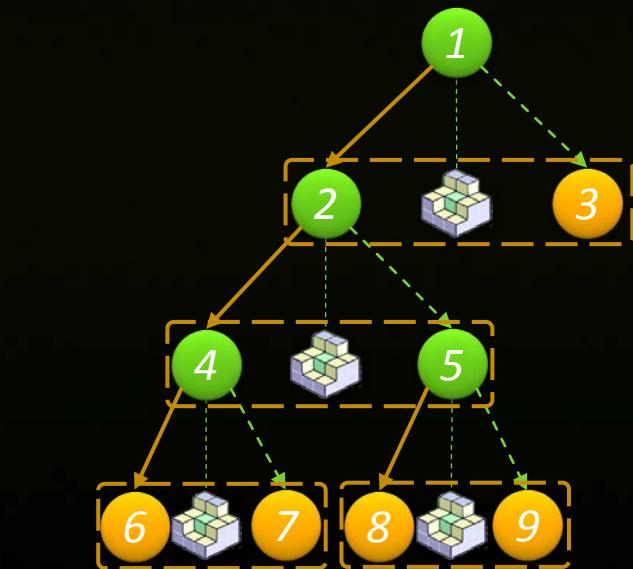
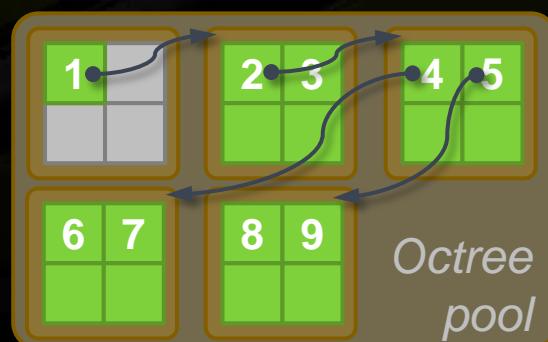
Settings

Off



# GPU Voxel Octree

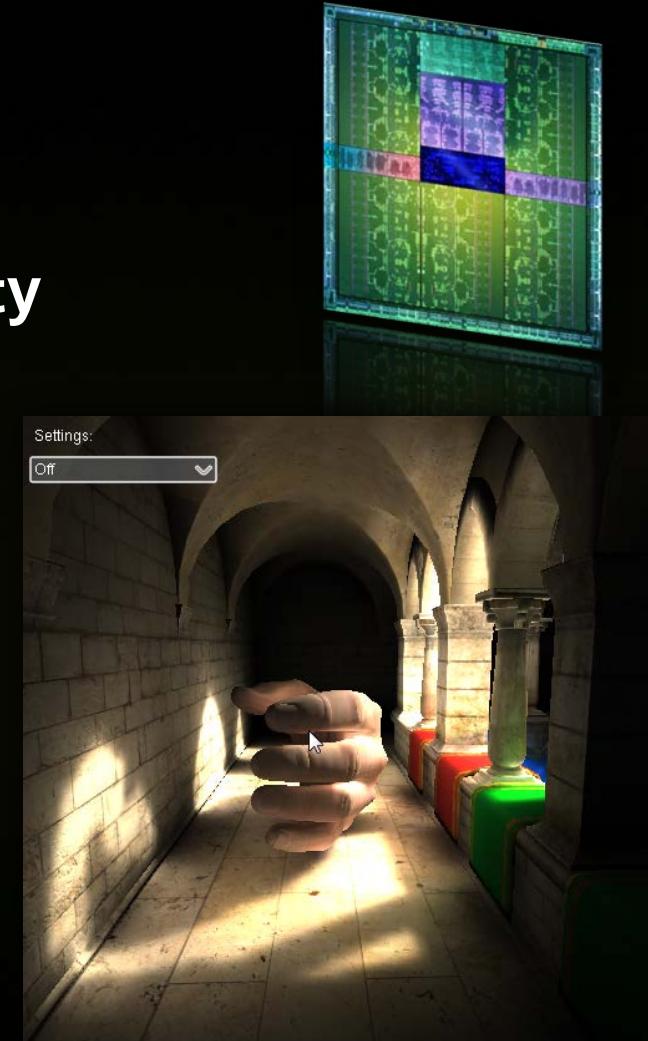
- Linked nodes in **linear video memory** (*Octree Pool*)
  - 2x2x2 nodes tiles
  - 1 pointer per node to a node-tile
- Voxels stored into a **3D texture** (*Brick Pool*)
  - Allows hardware tri-linear interpolation



# Hybrid rendering pipeline



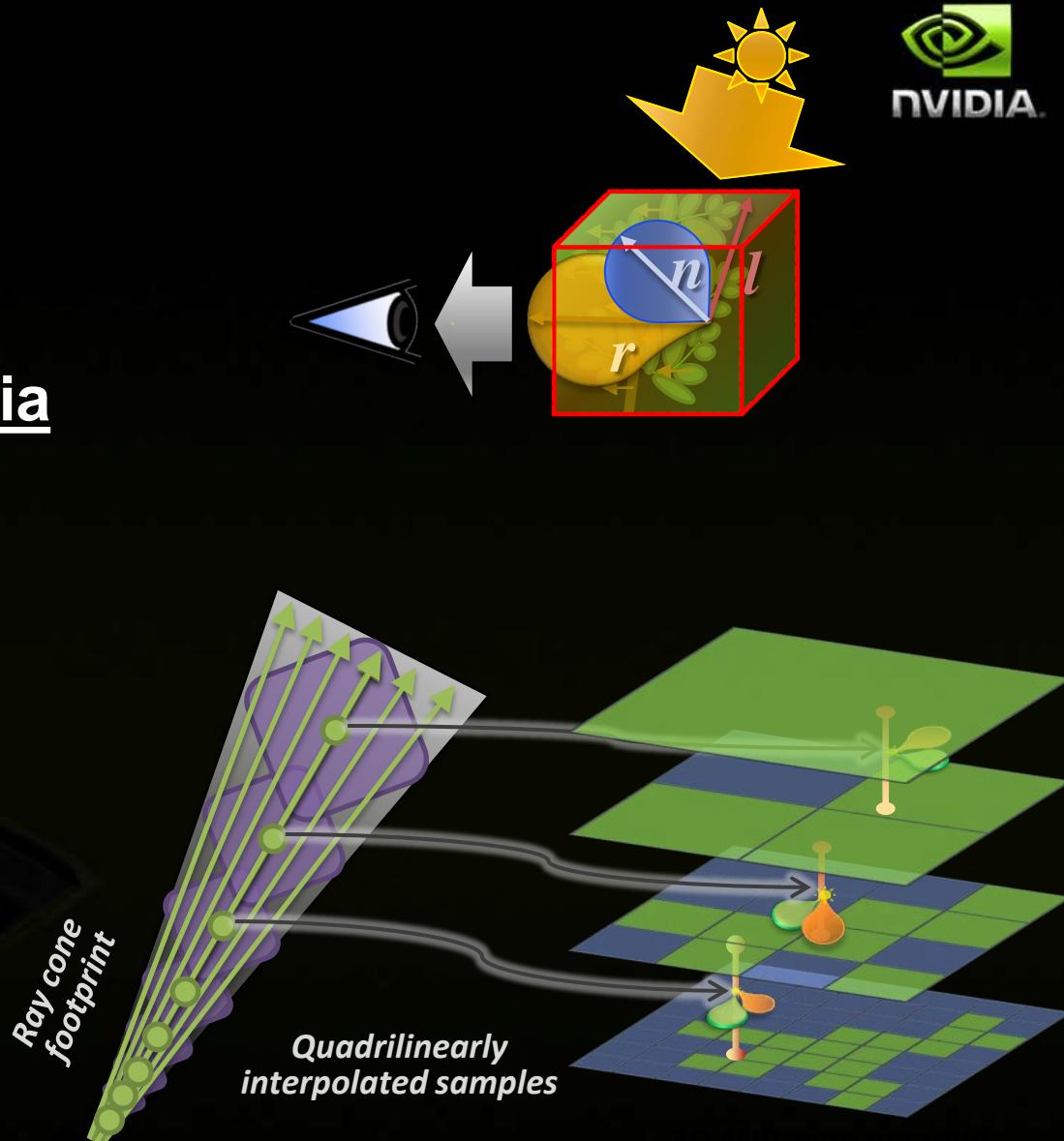
- Hybrid rendering pipeline
  - Rasterized primary rays
    - GPU pipeline optimized for direct visibility
  - Cone-traced secondary rays
    - Flexibility and scalability
- Forward or deferred rendering



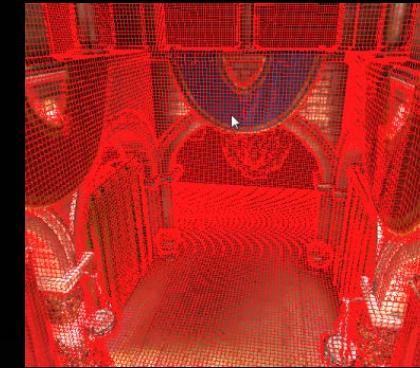
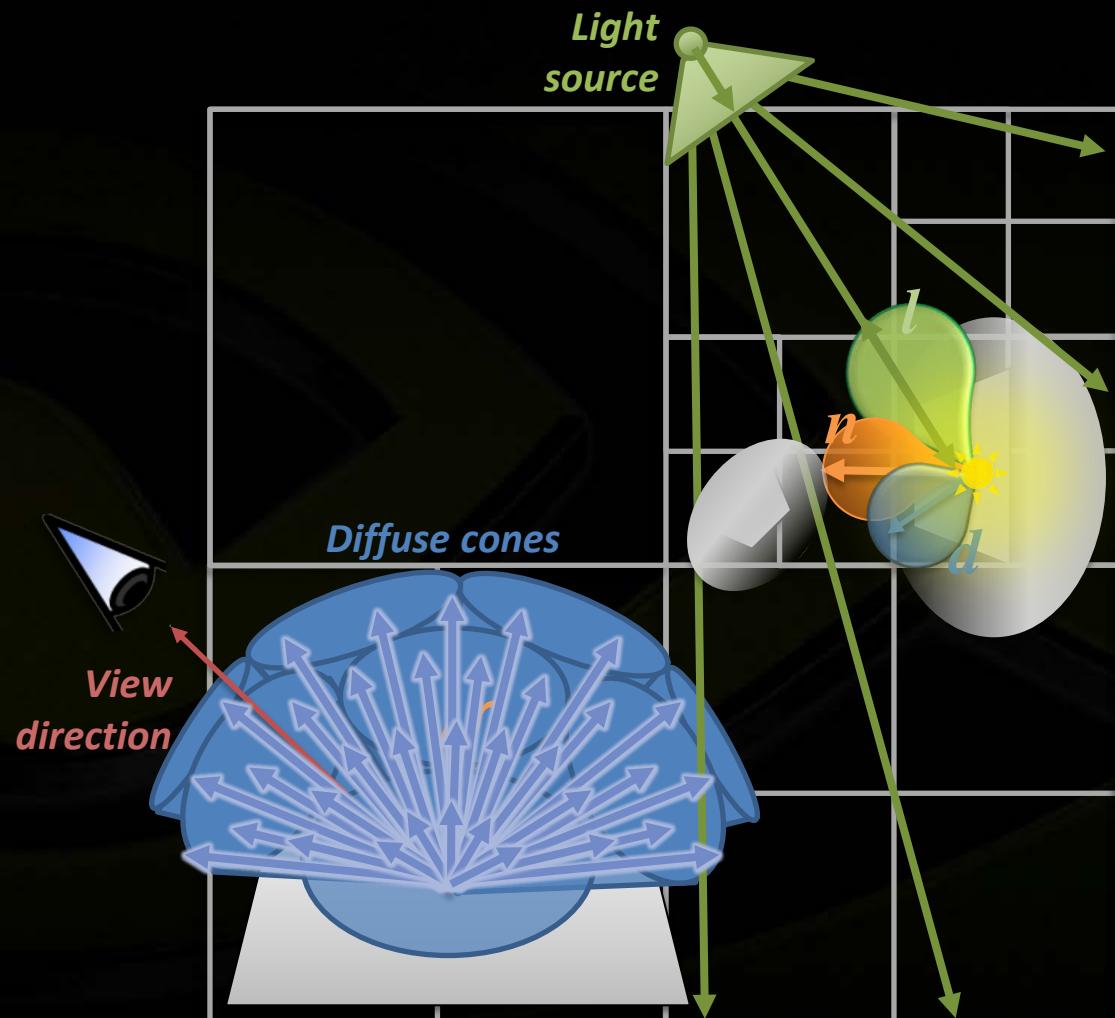
# Voxel cone tracing



- **Geometry pre-filtering**  
Traced like a participating media
  - Volume ray-casting
- **Voxel representation**  
Scene geometry : Opacity field  
+ Incoming radiance



# Rendering algorithm

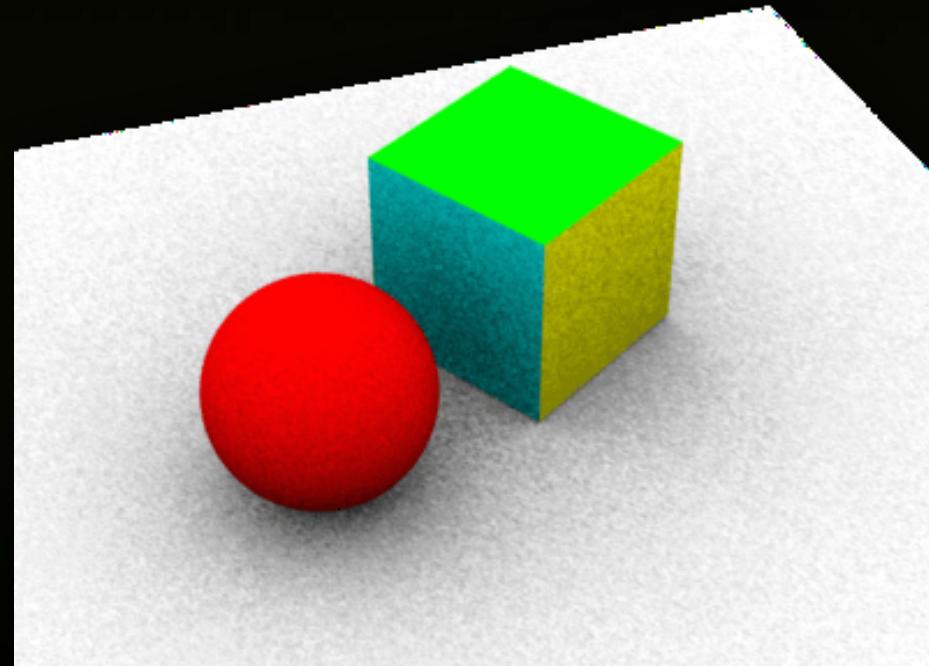


1. **Light pass (es)**
  - *Bake irradiance (RSM)*
2. **Filtering pass**
  - *Down-sample radiance in the octree*
3. **Camera pass**
  - *For each visible fragment: Gather indirect radiance*

# Discussion



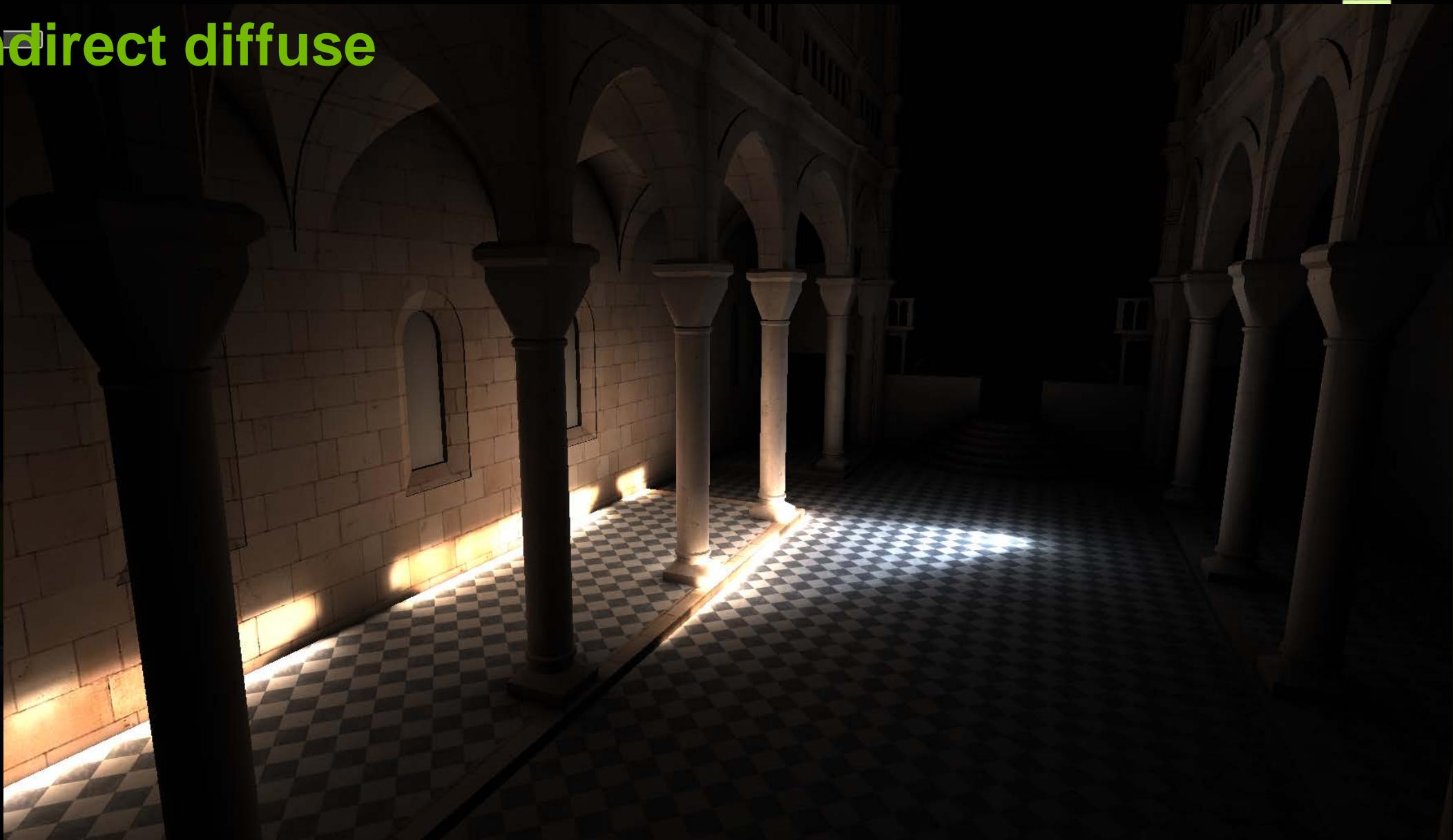
- **Scalable lighting rep. !**
  - **Independent of geometric complexity**
  - **Control over rendering time**
- **Large cones**
  - Precision / Light leaking
- **But always smooth**
  - Never noisy !!



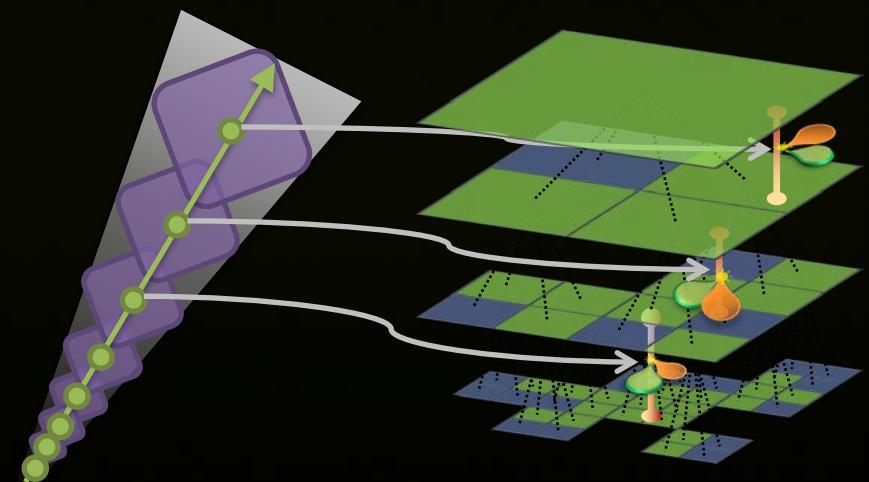
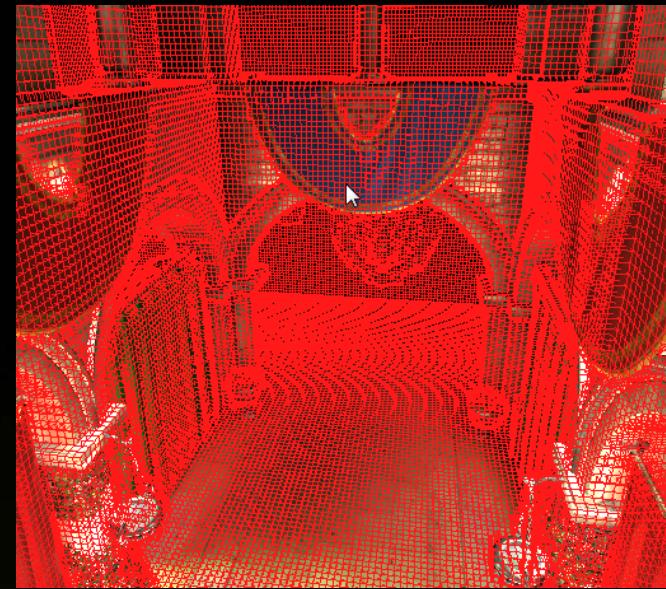
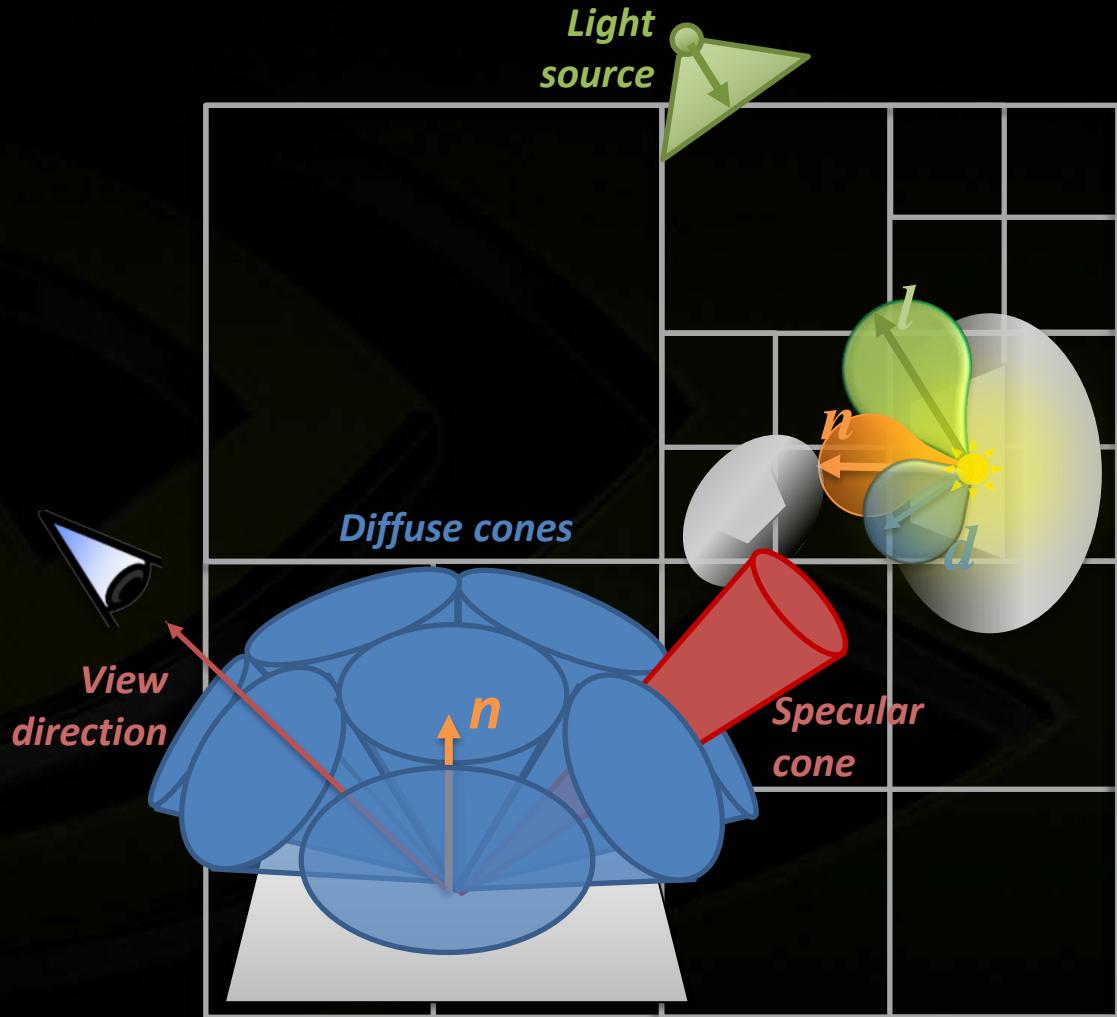
# Indirect diffuse



# Indirect diffuse



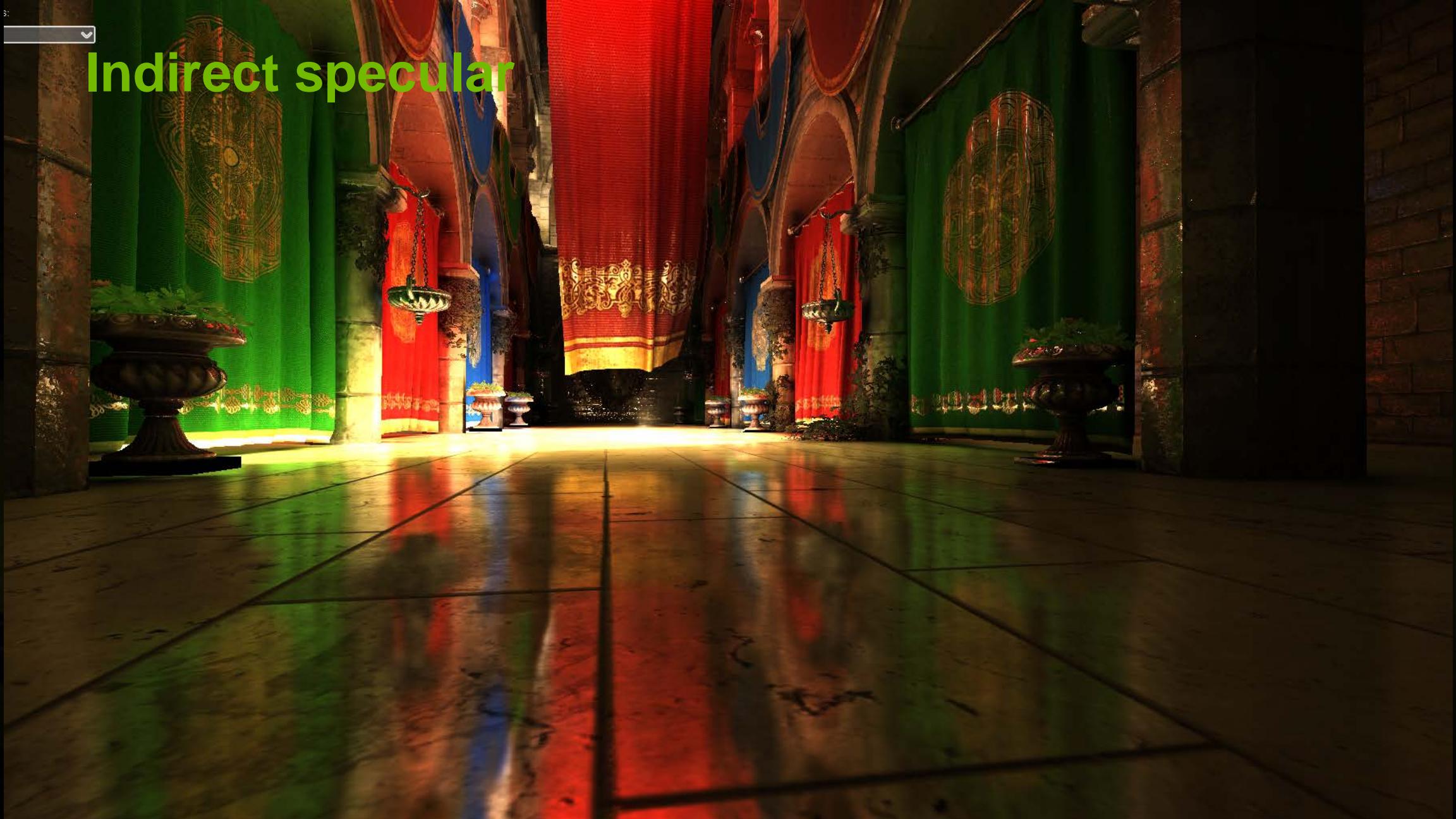
# Specular tracing



# Indirect specular



Indirect specular



Settings:

Indirect specular config

Cone half-angle: 0.000

Radiance multiplier: 1.136



Settings:

Off



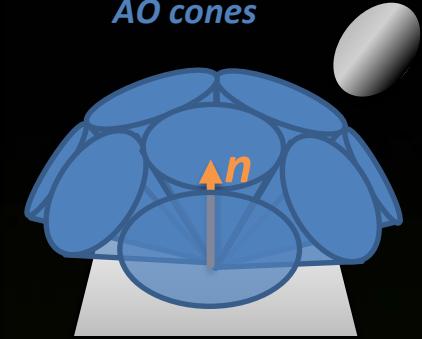
# Multiple-bounces



# Voxel Ambient Occlusion



*AO cones*



+ Distant +  
off-screen  
occlusions

- Resolution

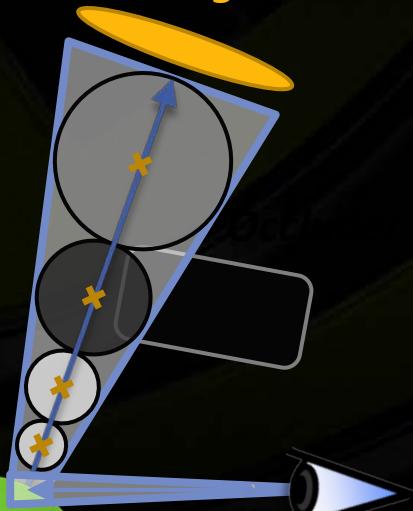
5.5ms @ 1280x720

# Voxel soft shadows

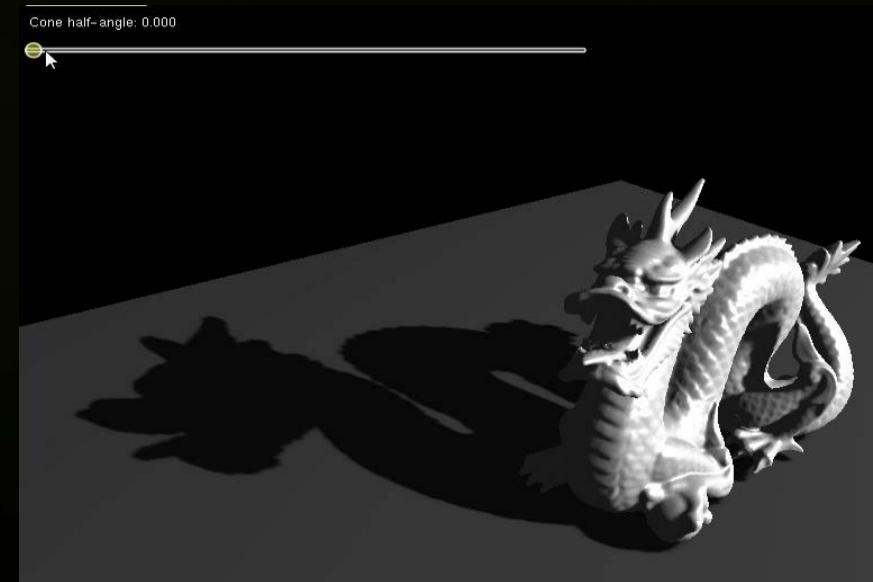
- One cone per pixel

*The smoother, the faster to compute !*

*Area light source*



**3-9ms @ 1280x720**



Settings:  
Off

# Publications

# *Interactive indirect illumination using voxel cone tracing*

**C. Crassin, F. Neyret, M. Sainz, S. Green, E. Eisemann**

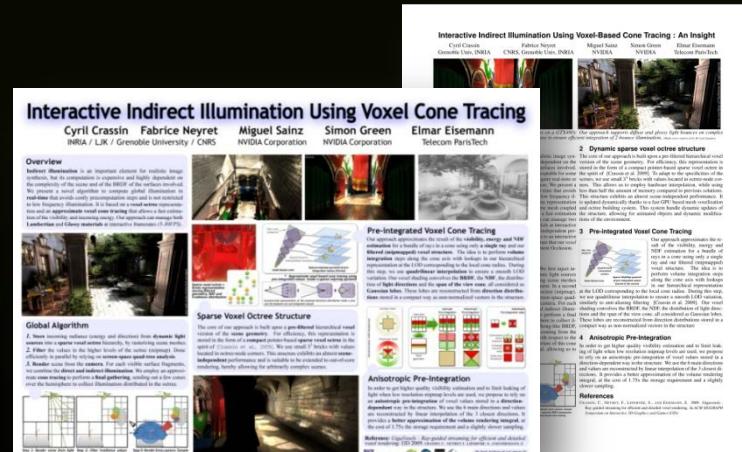
- Computer Graphics Forum  
*(Proc. of Pacific Graphics 2011)*
  - <http://research.nvidia.com/publication/interactive-indirect-illumination-using-voxel-cone-tracing>

# I3D 2011 Poster

<http://maverick.inria.fr/Publications/2011/CNSGE11/>

# *Siggraph 2011 Talk*

<http://maverick.inria.fr/Publications/2011/CNSGE11a/>



# Dynamic Voxelization

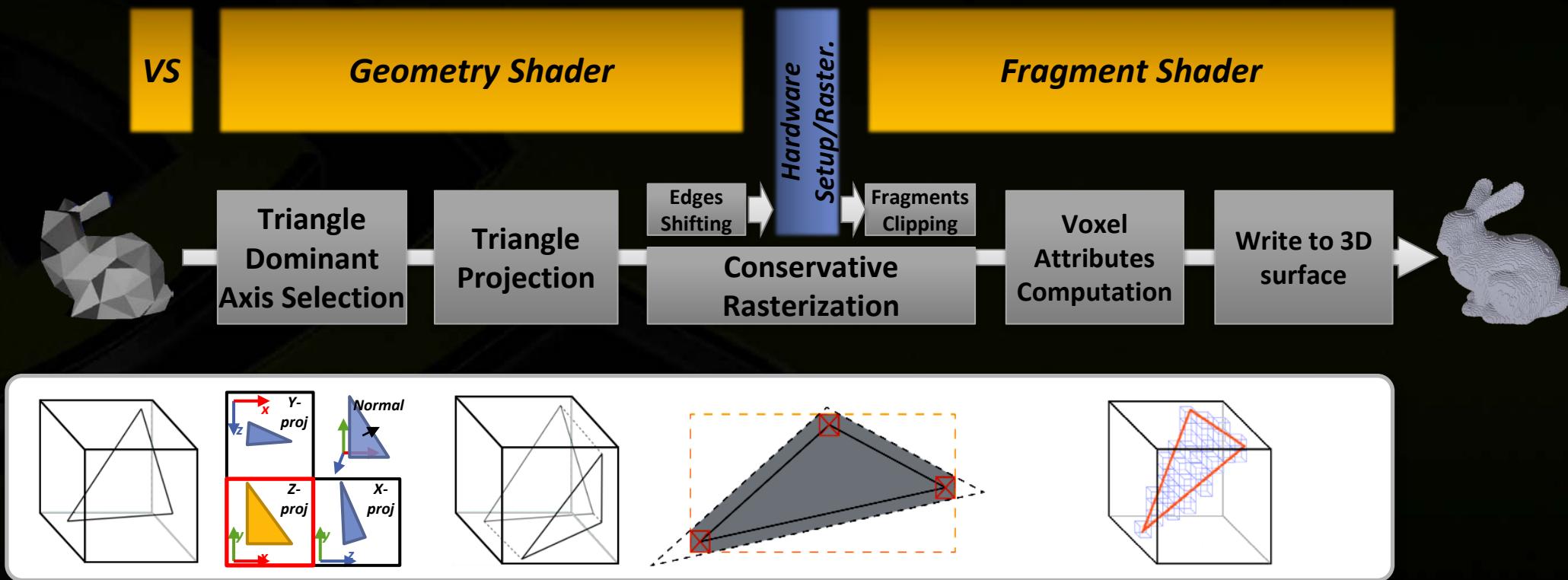


- Entirely done using the GPU graphics pipeline
  - Sparse (No plain grid allocation)
- Two modes :
  - Static environment
    - Pre-voxelized (~20ms)
  - Dynamic objects
    - Added to the structure at runtime (~4-5ms)



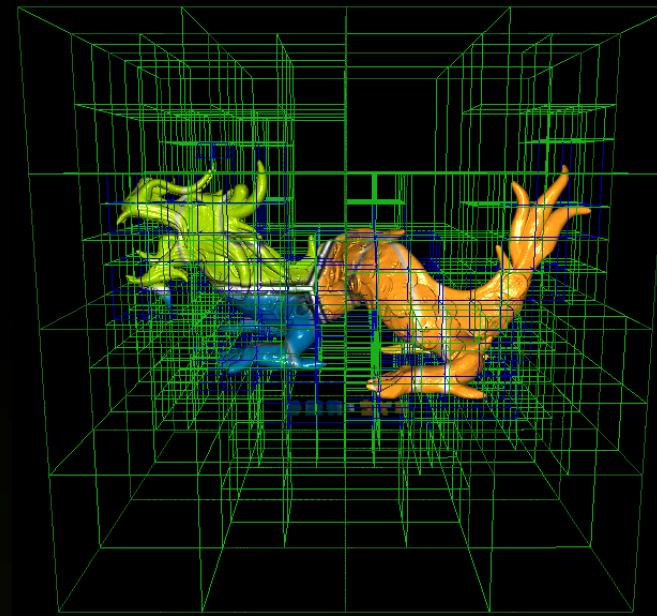
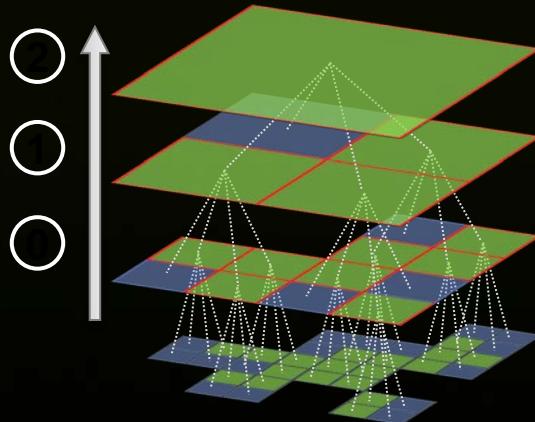
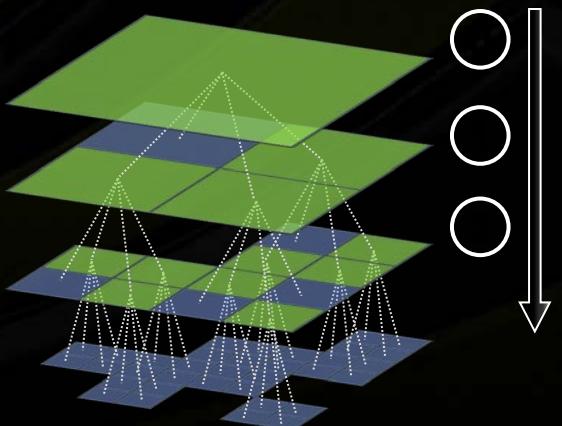
# One pass voxelization pipeline

- *Thin surface voxelization*



# Sparse Octree construction

- **Sparse voxelization**
  - No plain grid allocation
- Two steps:
  1. Octree subdivision

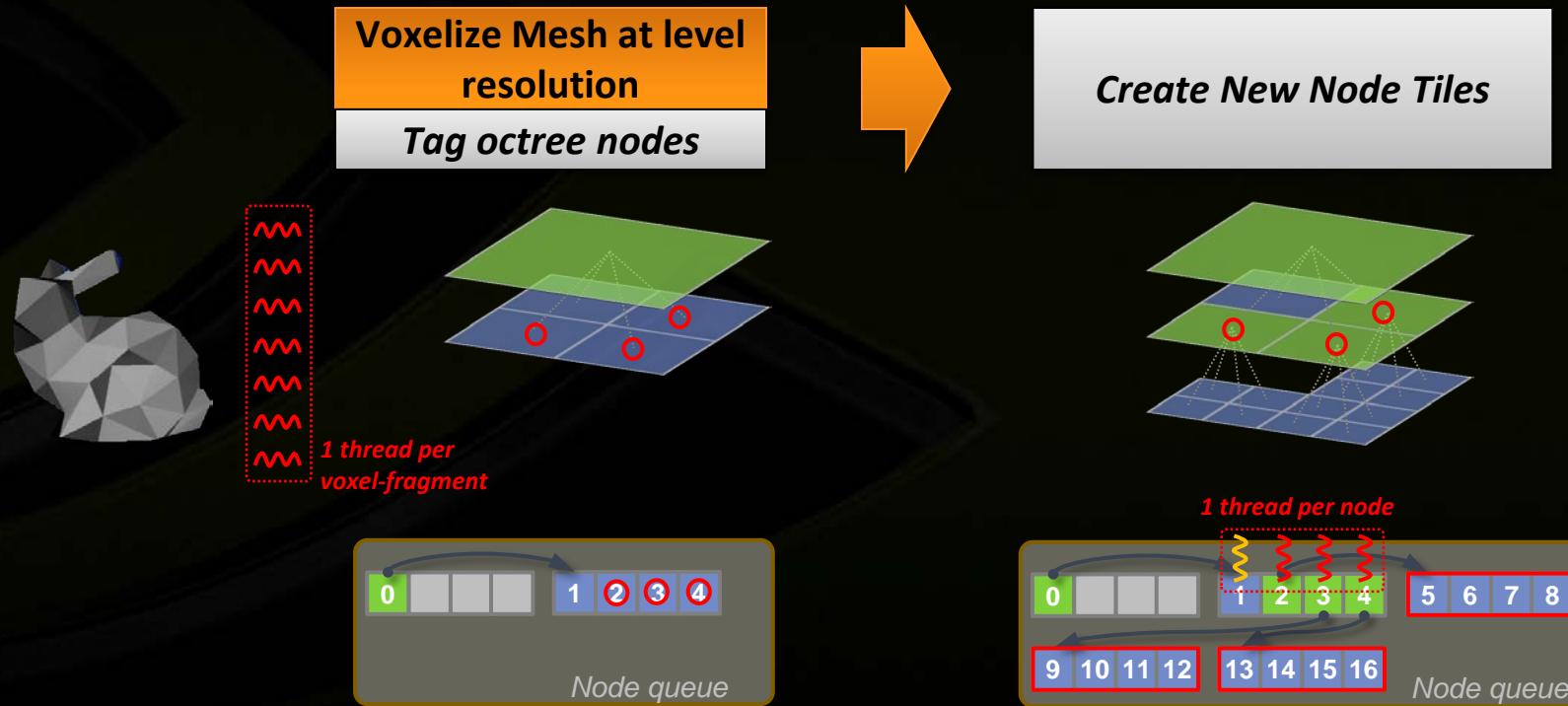
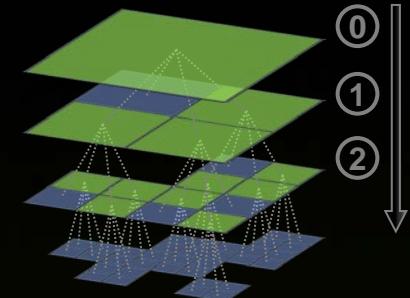
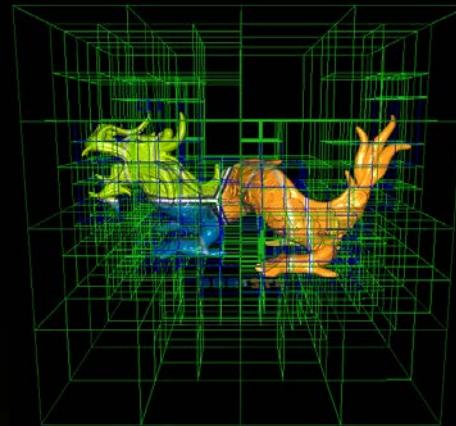


2. Values MIP-mapping

# Octree construction

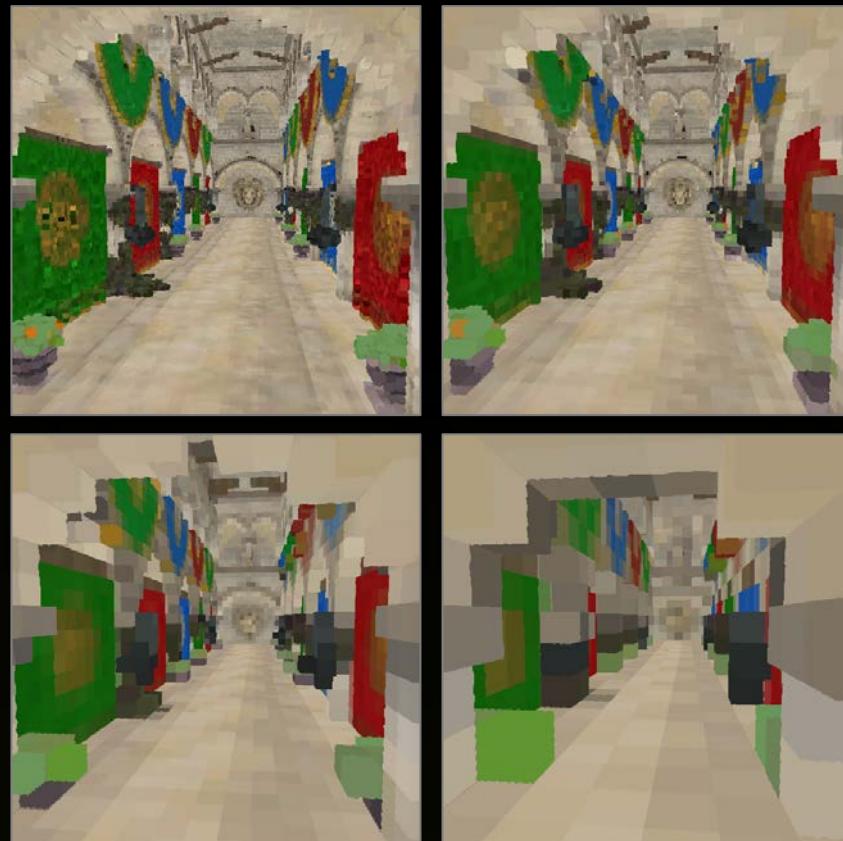


- Top-down octree construction
- Compute + Graphics



# Results

- 9 levels octree ( $512^3$ )
- RGBA32F
- Kepler GK104 performance
  - 30% - 58% faster than Fermi GF100
  - Atomic merging up to 80% faster.



Times in ms	Frag list	Octree construction				Write	MIP map	Total
		Flag	Create	Init	Total			
Scene								
Sponza	2.07	5.65	0.37	1.32	7.34	3.94	2.09	15.44

# OpenGL Insights

- *Octree-Based Sparse Voxelization Using The GPU Hardware Rasterizer*

Cyril Crassin and Simon Green

- Just released at Siggraph 2012  
Patrick Cozzi & Christophe Riccio





**THANKS !**



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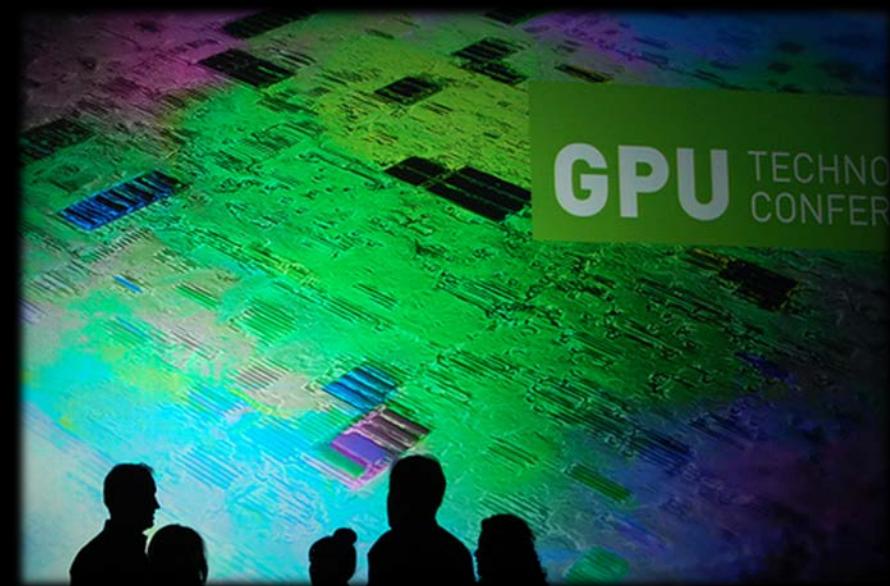
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