

ASTRONOMY-INSPIRED VISUAL COMPUTING

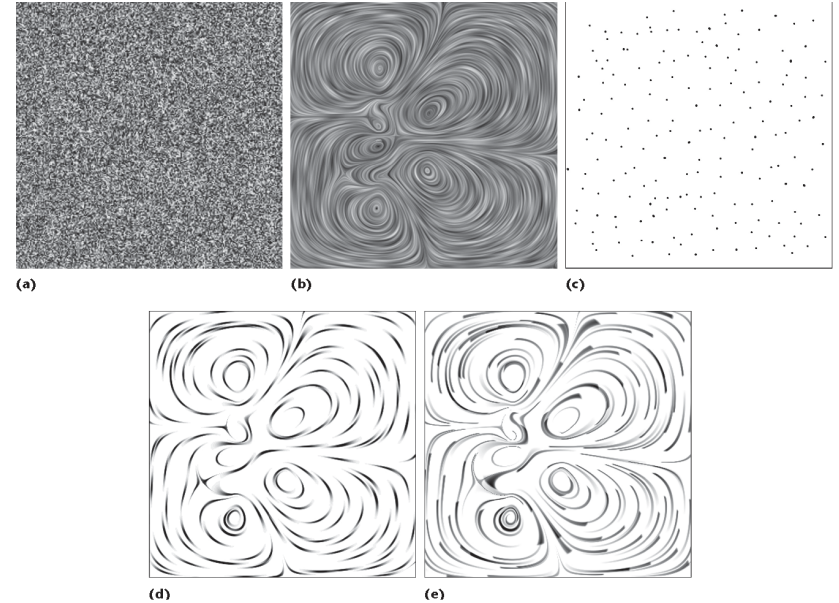
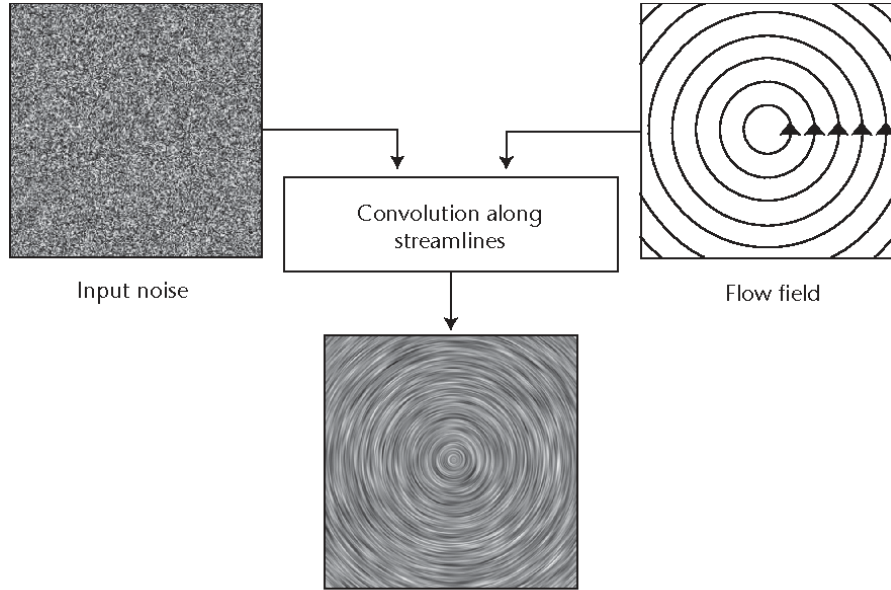
AMITABH VARSHNEY

UNIVERSITY OF MARYLAND



Star Trails over Oregon by Joshua Bury
NASA Astronomy Picture of the Day, Sep 9, 2009

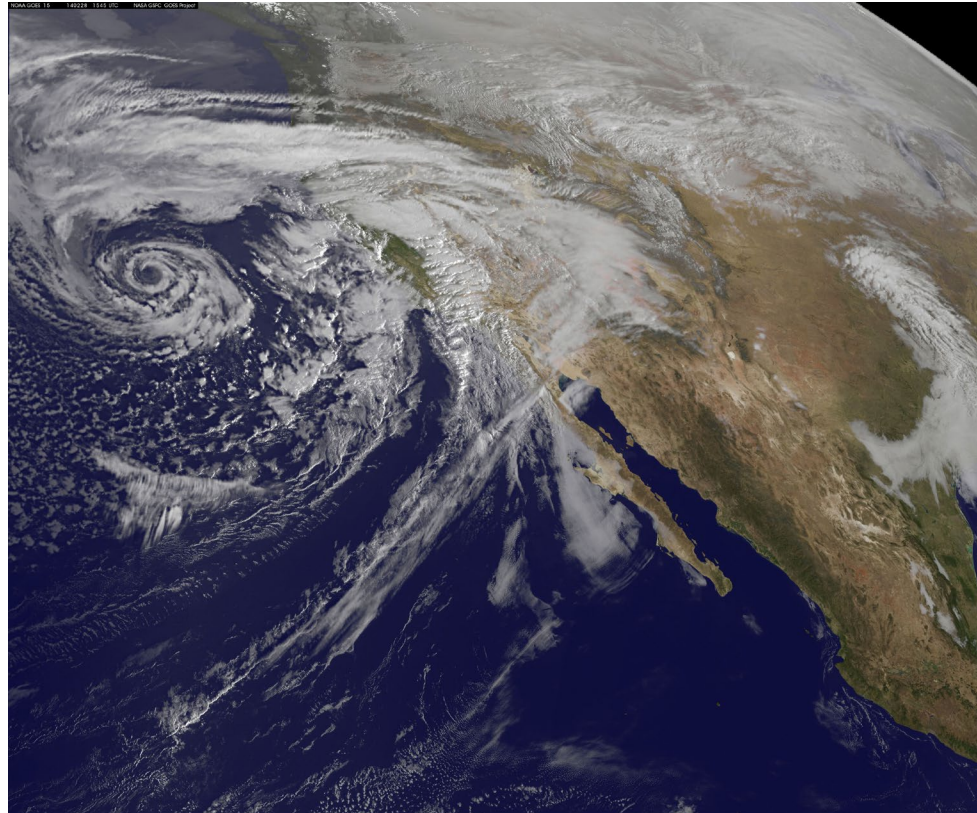
LINE INTEGRAL CONVOLUTION



Cabral and Leedom, SIGGRAPH 1993

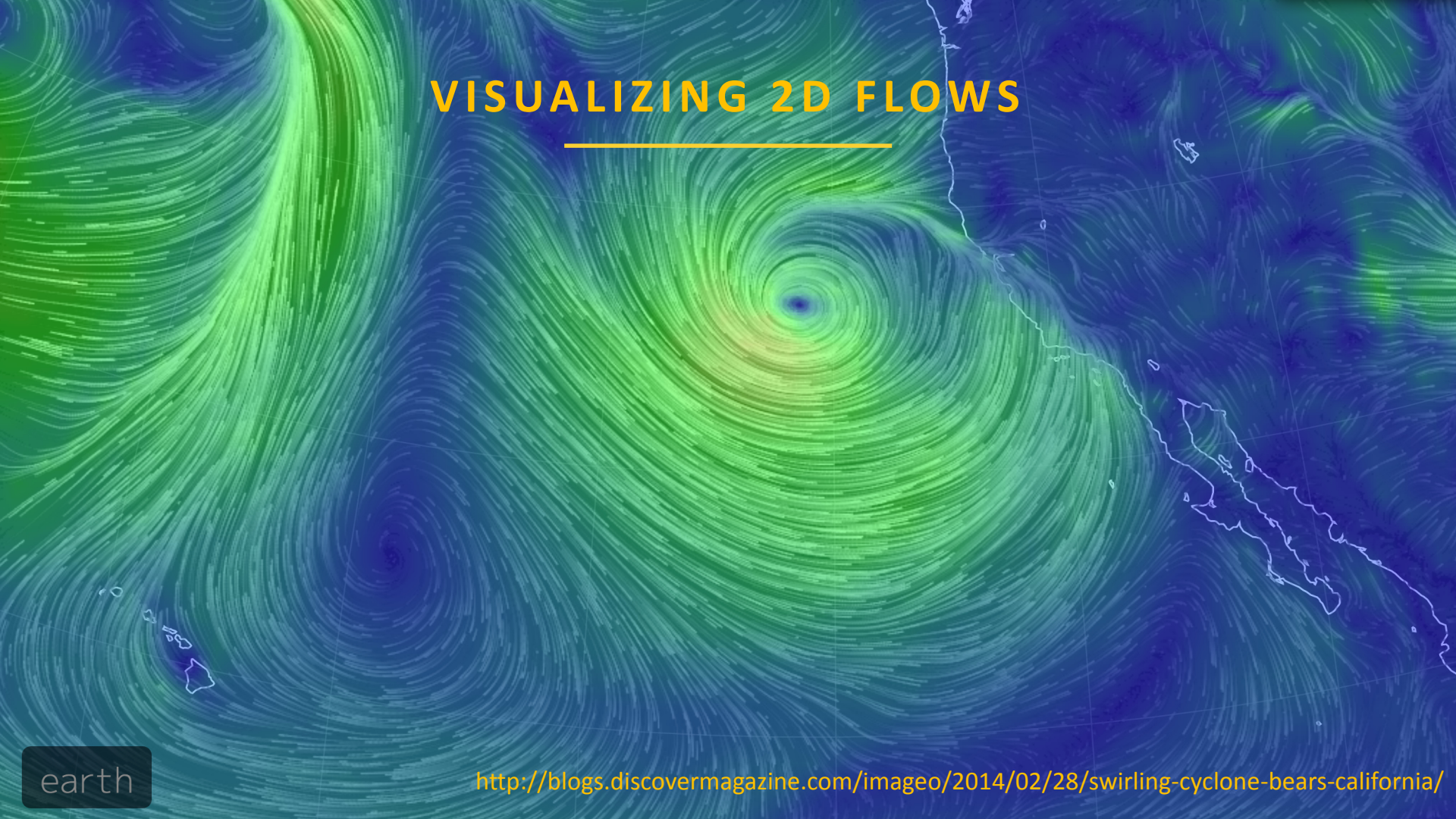
Images here from Netzel and Weiskopf, Computing in Science and Engg, 2013

WEATHER IMAGE

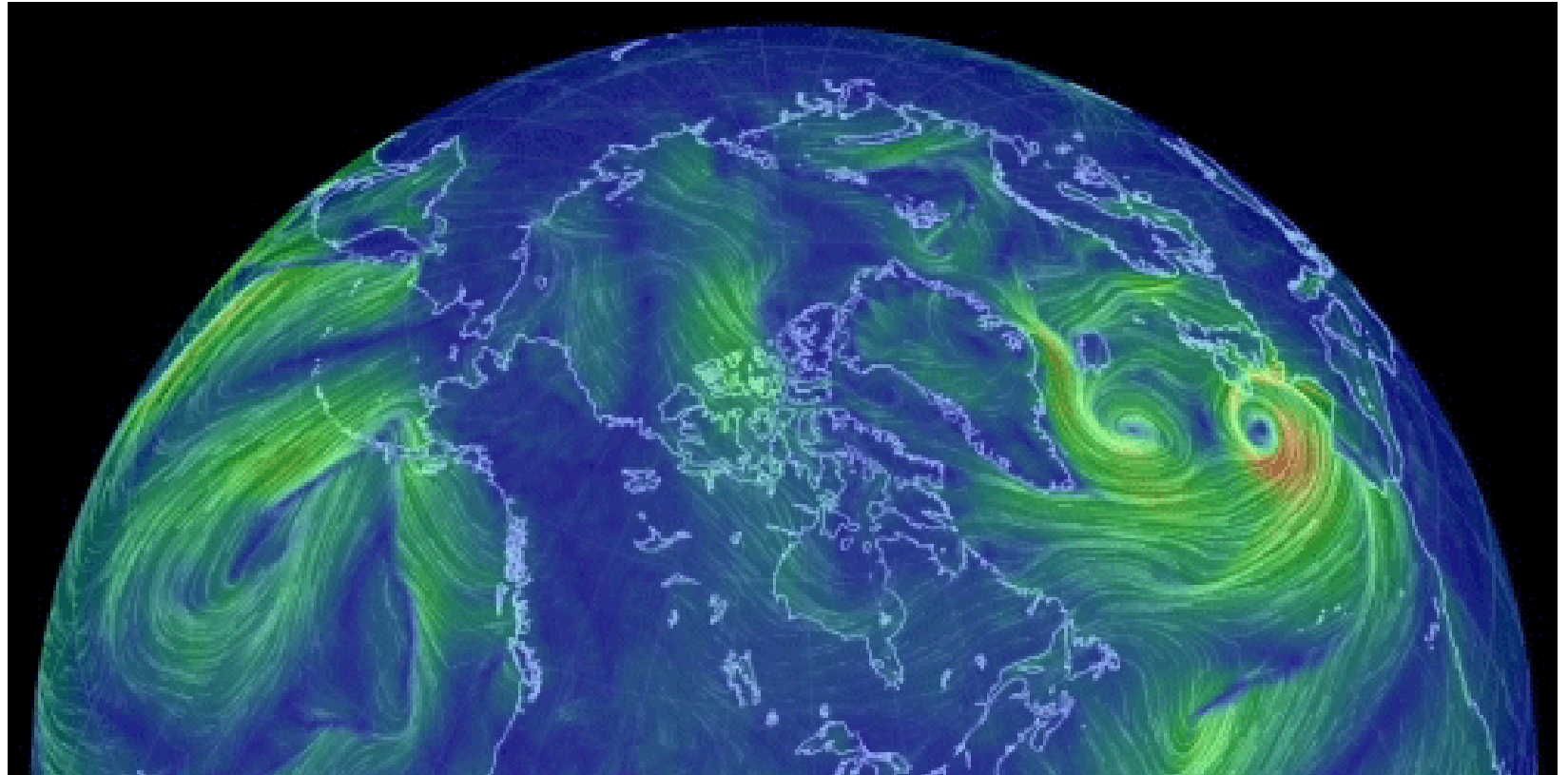


<http://blogs.discovermagazine.com/imageo/2014/02/28/swirling-cyclone-bears-california/>

VISUALIZING 2D FLOWS

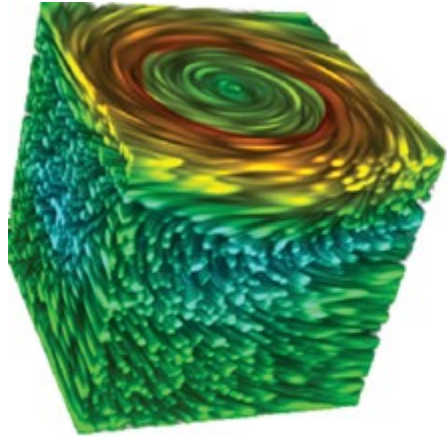


ANIMATING 2D FLOWS

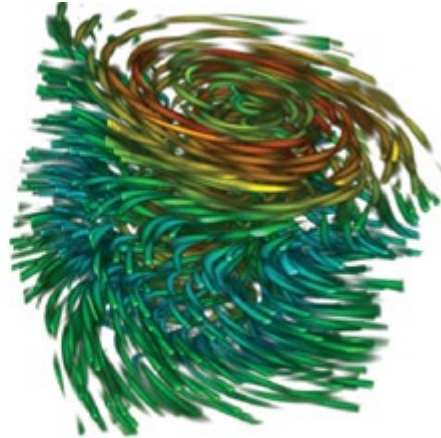


<http://thescienceofreality.tumblr.com/post/76158016319/global-wind-map>

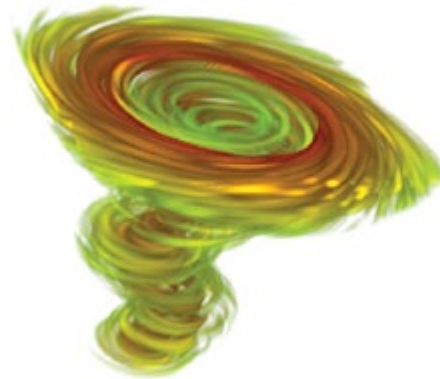
VISUALIZING 3D FLOWS



(a)



(b)



(c)



(d)

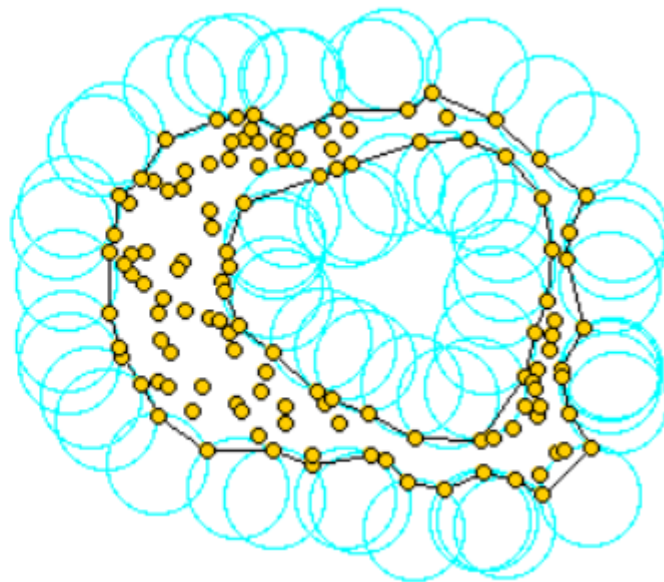
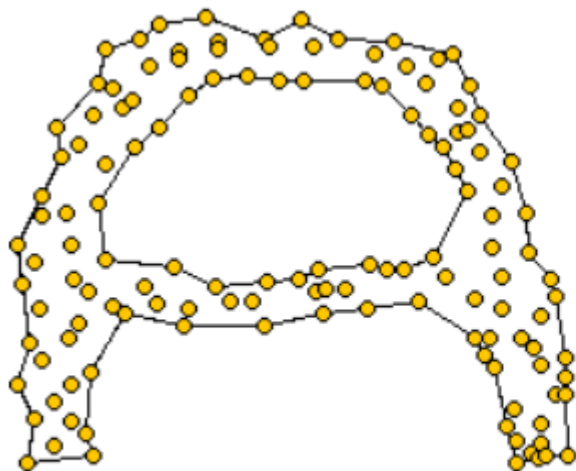
SHAPE OF A GALAXY



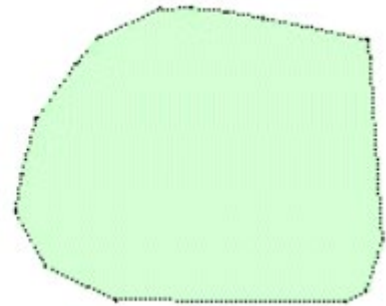
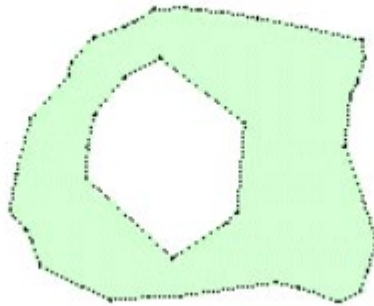
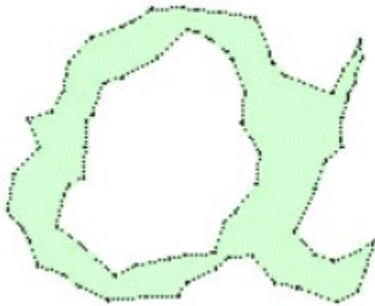
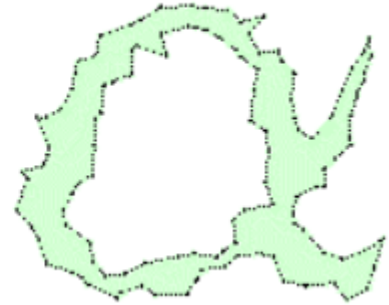
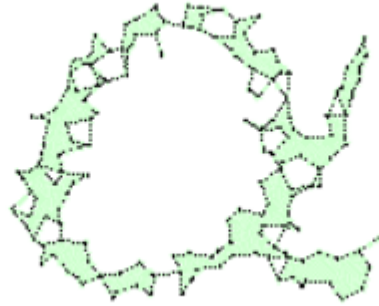
<https://www.nasa.gov/image-feature/goddard/2016/hubble-spies-a-spiral-snowflake>

<https://astronomy.stackexchange.com/questions/1145/why-are-galaxies-disk-shaped>

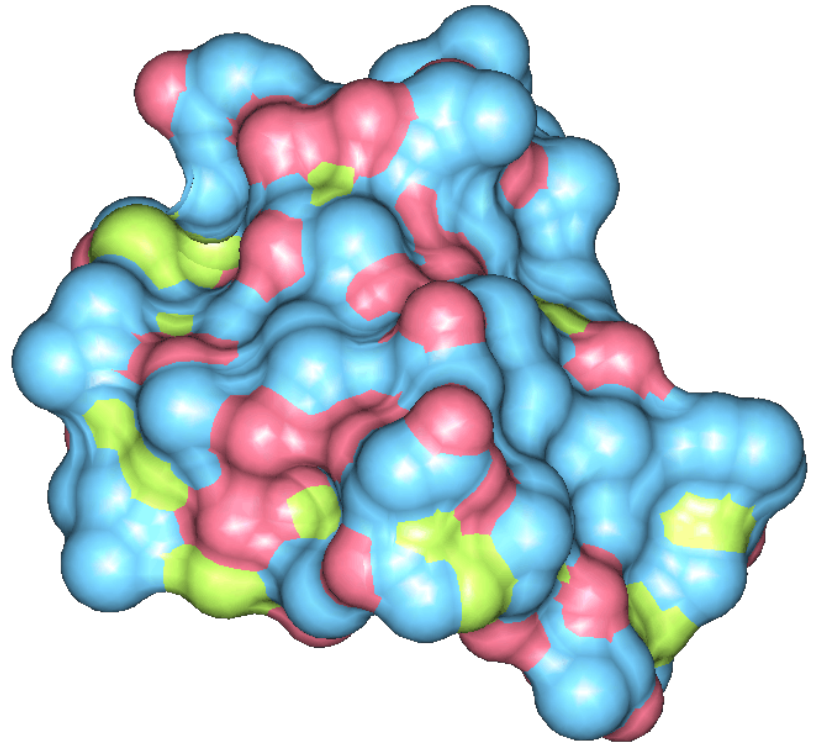
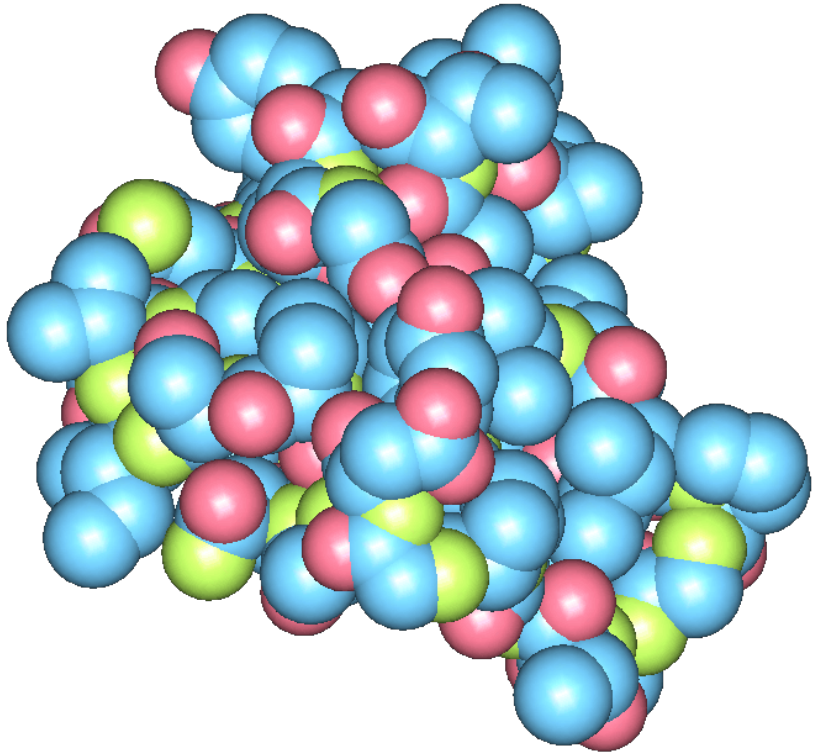
ALPHA HULLS



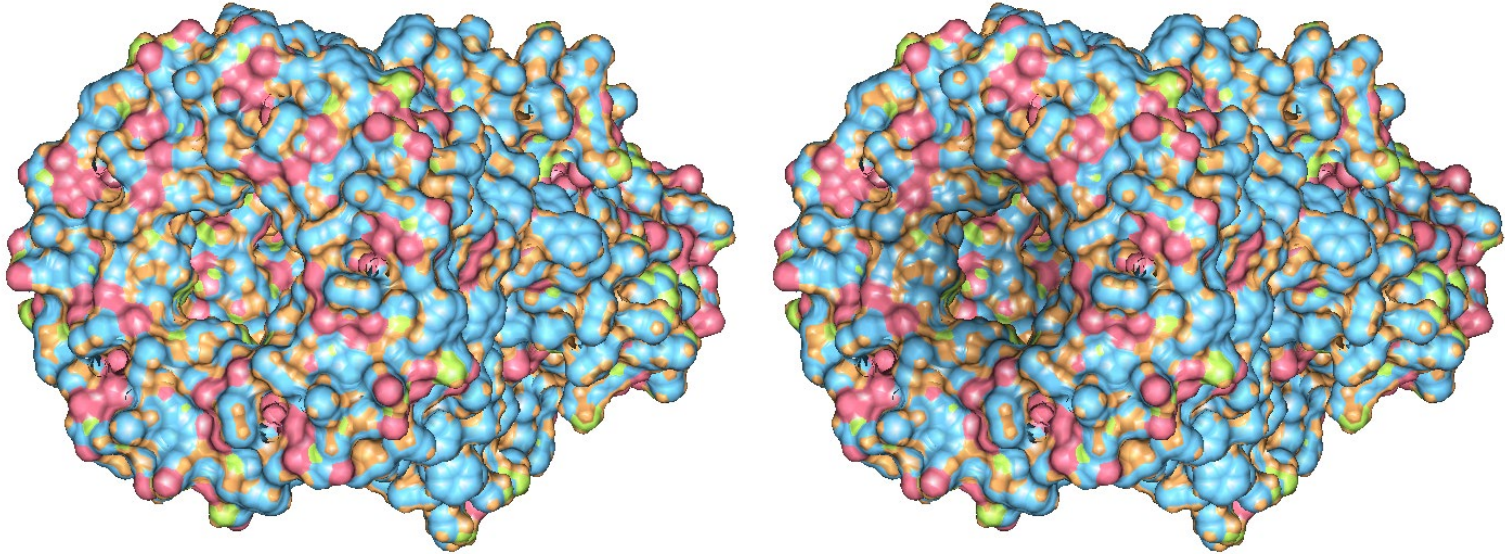
ALPHA HULLS



SMOOTH MOLECULAR SURFACES

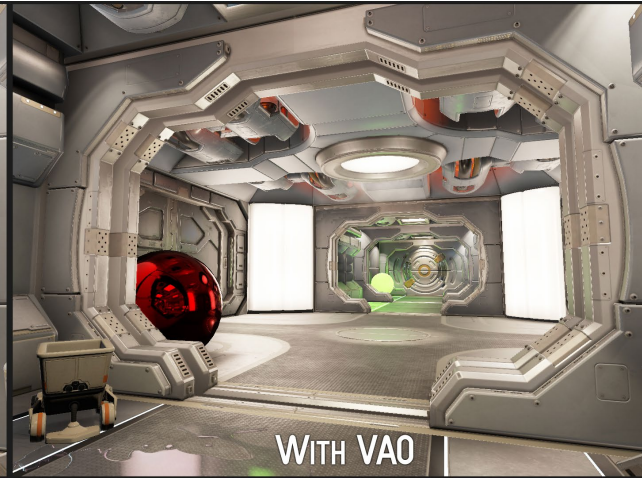


MULTISCALE ACCESSIBILITY LIGHTING



VOLUMETRIC AMBIENT OCCLUSION

SCENE BY UNITY TECHNOLOGIES



<https://forum.unity.com/threads/volumetric-ambient-occlusion-image-effect.428426/>

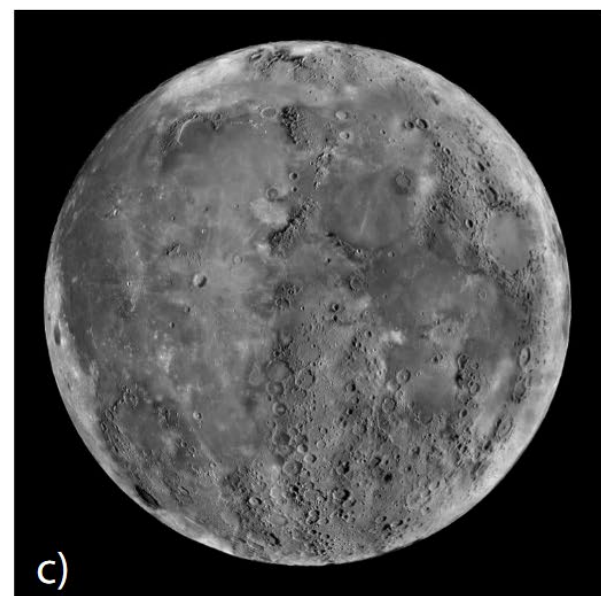
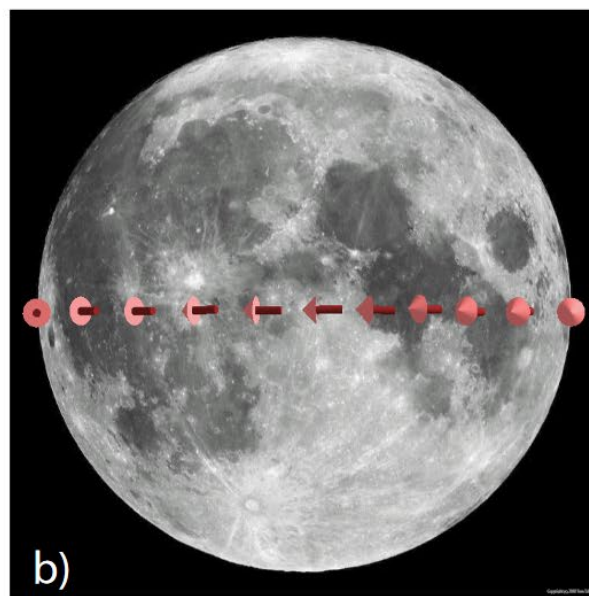
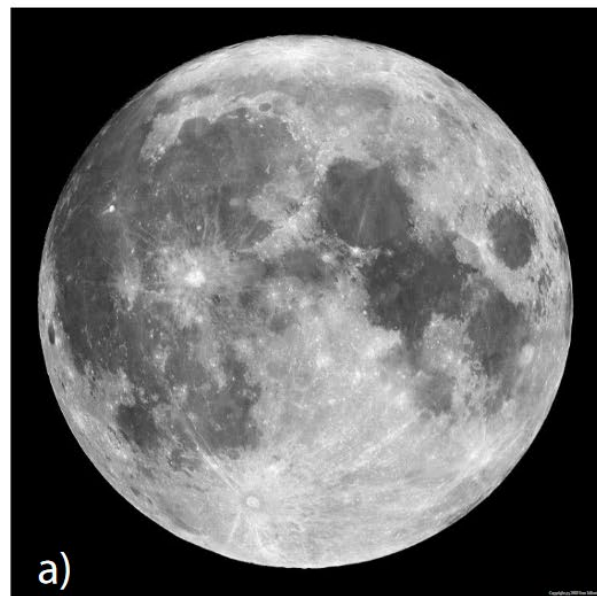
LIGHTING



Copyright © 2002 Tom Talbott

<https://www.flickr.com/photos/moonphaser/22168942/in/gallery-bunnyfrogs-72157624641457961>

LIGHTING

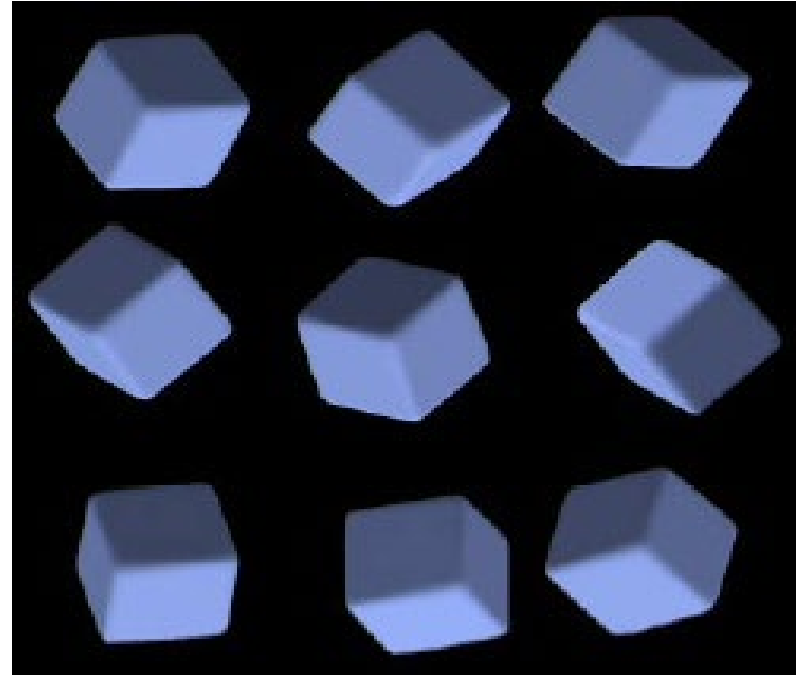


ILLUMINATION INCONSISTENCIES

Illumination consistency is *not* resolved at the low-level human vision

Find the cube lit inconsistently
with respect to others:

*On average, users take 8 seconds
to answer and are then wrong
30% of the time*



Ostrovsky, Sinha, Cavanagh, *Perception* 2006

DISCREPANT LIGHTING IN ART

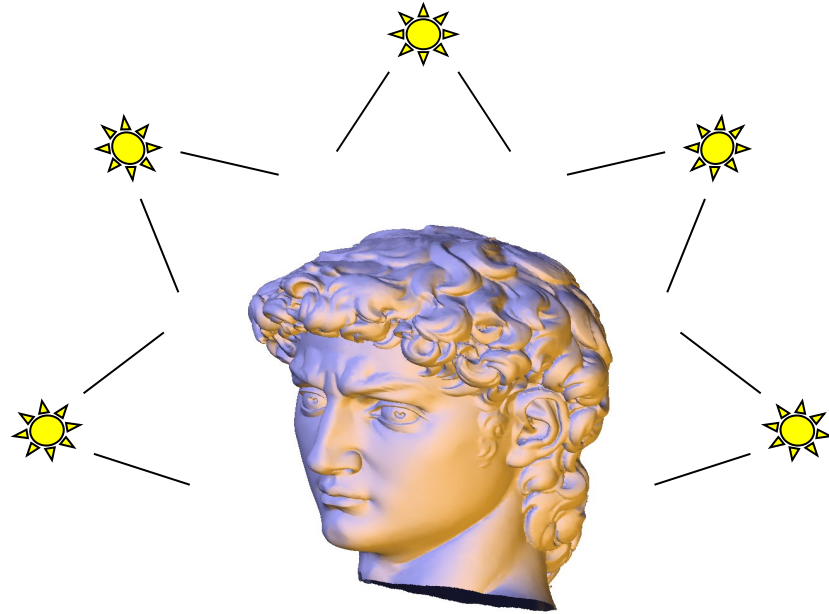


George Washington Crossing the Delaware
by Emanuel Gottlieb Leutze

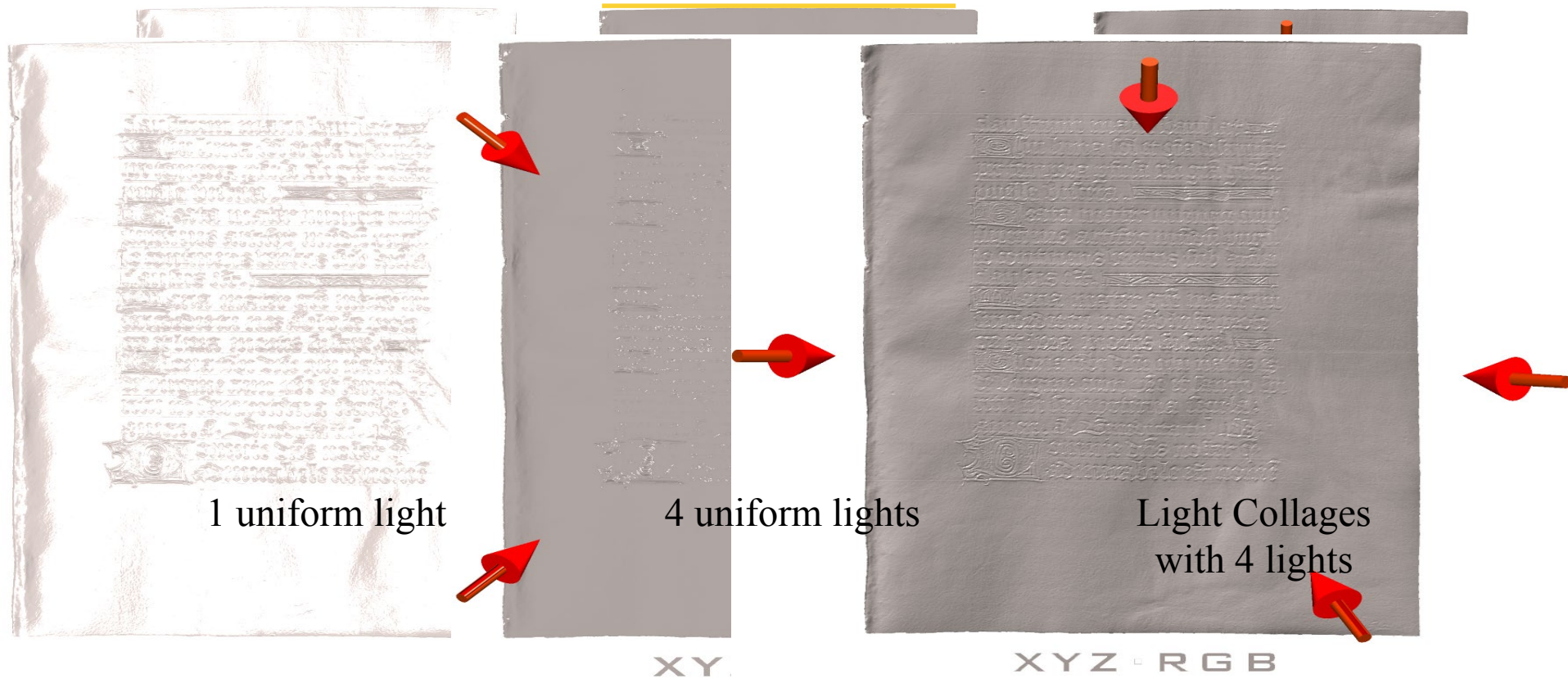
LIGHT COLLAGES

Use local lights

Seamlessly blend

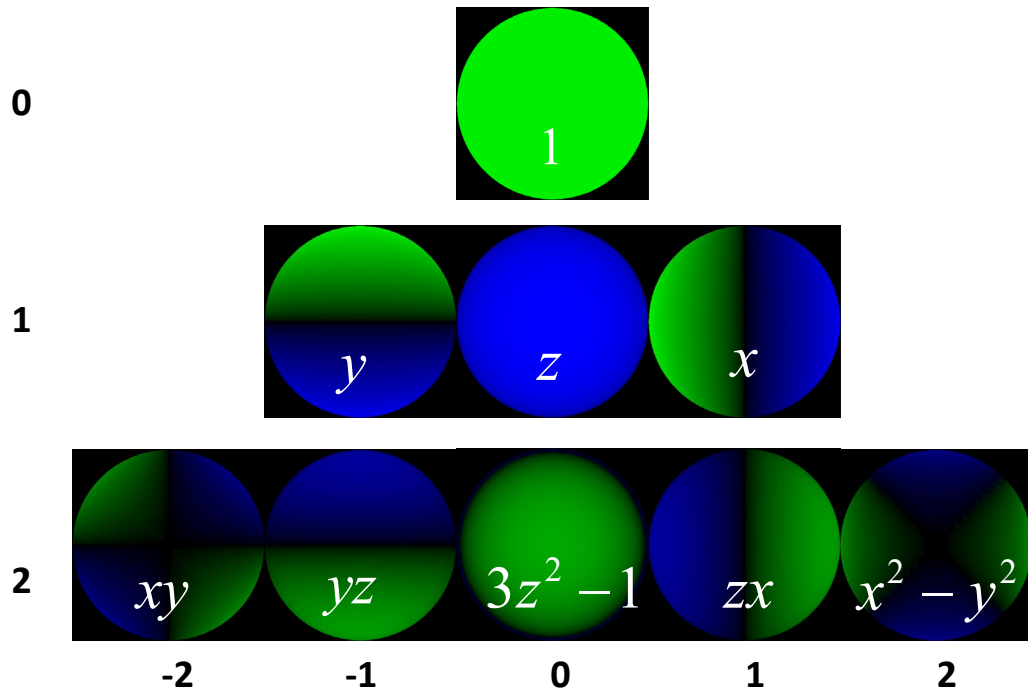


LIGHT COLLAGES: MANUSCRIPT



Manuscript courtesy of Paul Debevec, USC and XYZ RGB Inc.

SPHERICAL HARMONIC LIGHTING



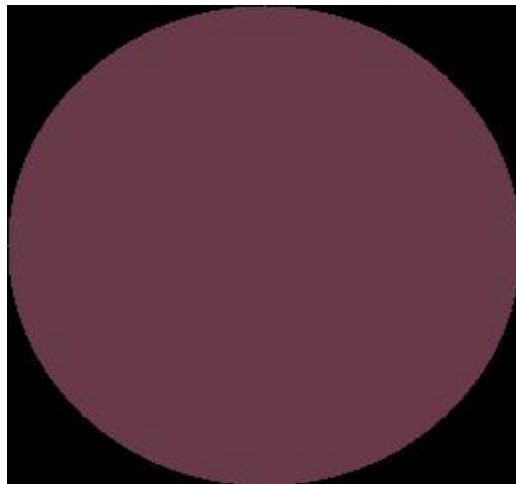
Basri and Jacobs 2000

Ramamurthy and Hanrahan 2001

SPHERICAL HARMONIC LIGHTING: 1 TERM

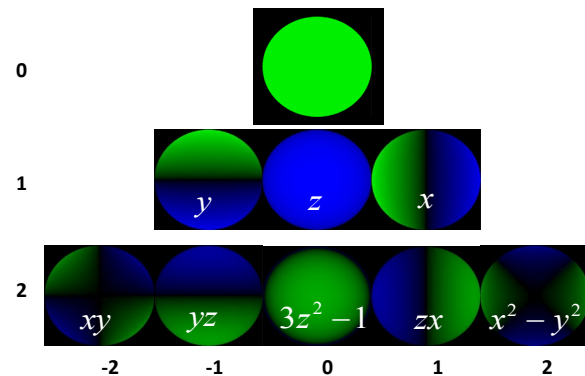


Exact image



RMS error = 25 %

Order 0
1 term



SPHERICAL HARMONIC LIGHTING: 4 TERMS

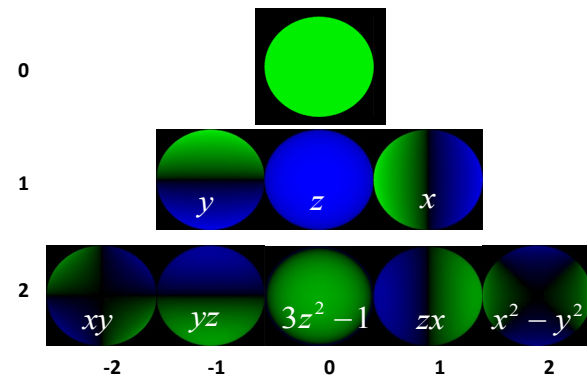


Exact image



RMS error = 8 %

Order 1
4 terms



SPHERICAL HARMONIC LIGHTING: 9 TERMS

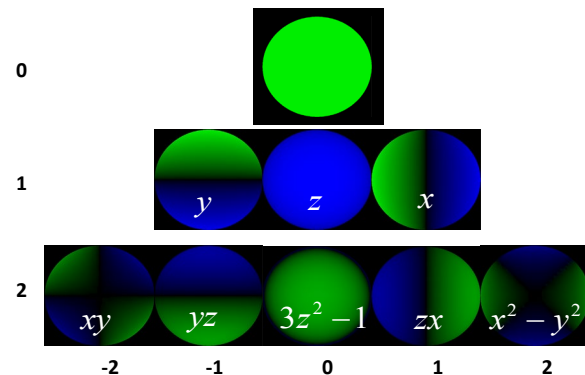


Exact image

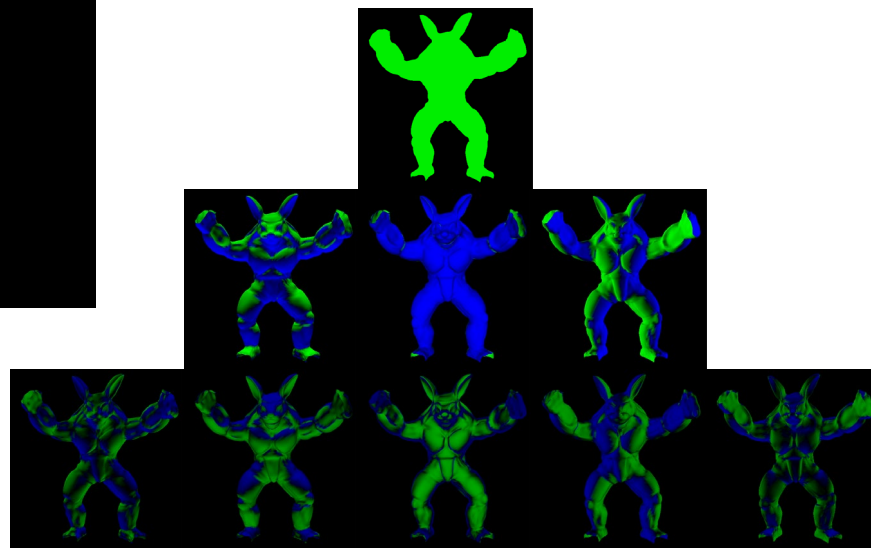
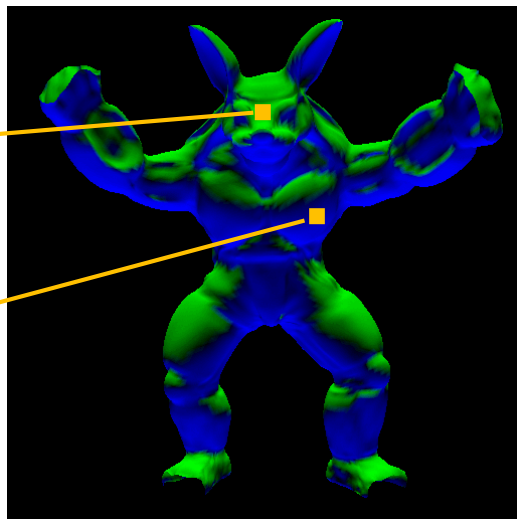
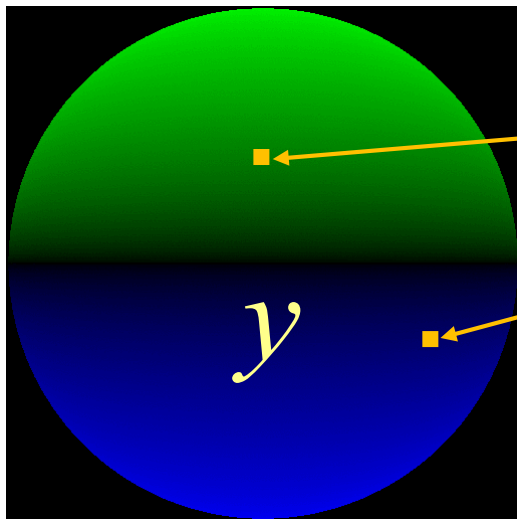


RMS error = 1 %

Order 2
9 terms



SPHERICAL HARMONIC LIGHTING: 9 TERMS

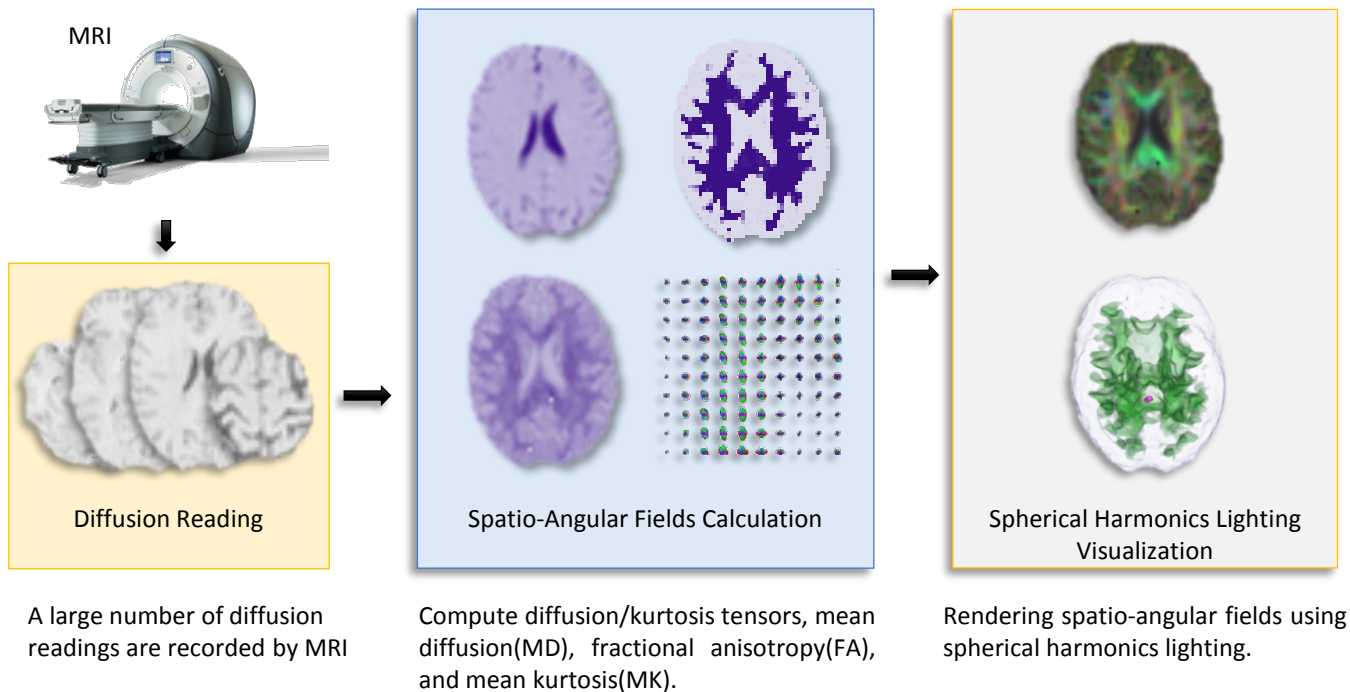


SPHERICAL HARMONIC LIGHTING



Fable Legends, Xbox One (Lionhead Studios)

VISUALIZING BRAIN MICROSTRUCTURE



SPHERICAL HARMONIC LIGHTING

- We compute spherical harmonics approximation of each kurtosis tensor
- Lighting functions are also expressed in spherical harmonics basis
- Light response = Dot product of the above two:

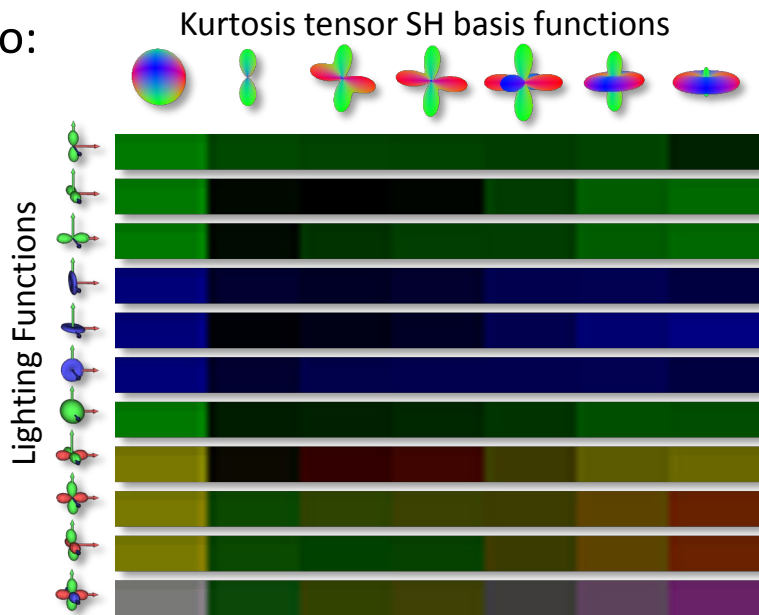
$$R_p = k \times \sum_{i=0}^{l^2} u_i(s) \cdot v_i(s)$$

Where,

k is scale

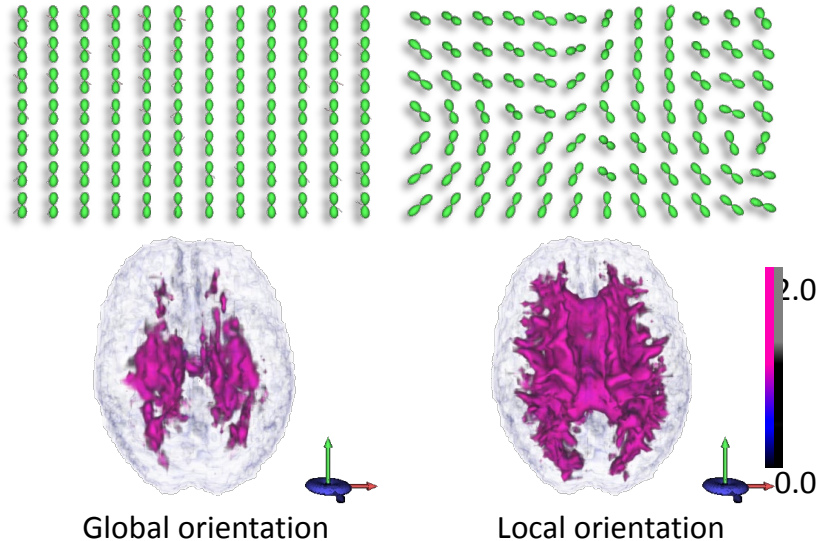
u_i is light SH coefficients

v_i is kurtosis SH coefficients



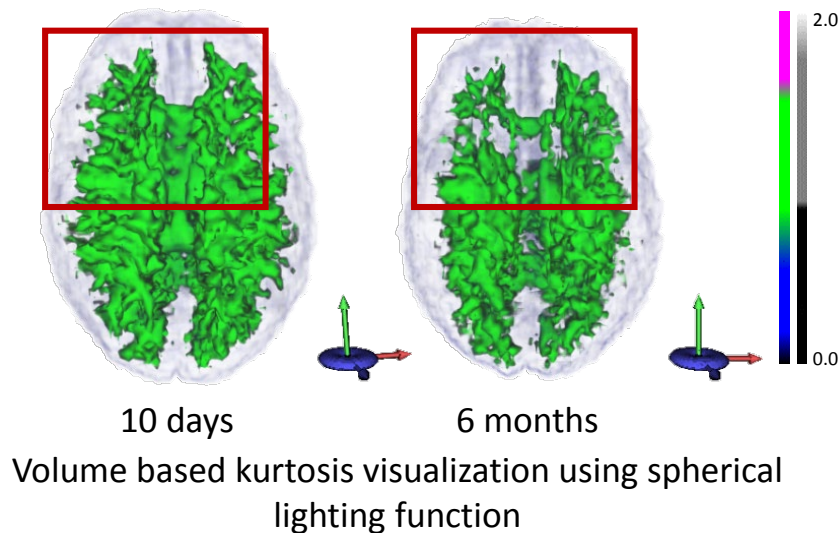
LIGHTING ORIENTATION: GLOBAL AND LOCAL

- Global: Same orientation for every voxel
- Local: Aligned to each voxel's principal diffusion direction
 - Use spherical harmonics rotation for efficiency



MILD BRAIN INJURY

- MRI taken 10 days and 6 months after injury
- Subtle injury without any lesion
- Post-concussive symptoms, declined cognitive function
- Brain atrophy visible using our approach



THE DEEP LEARNING CHALLENGE

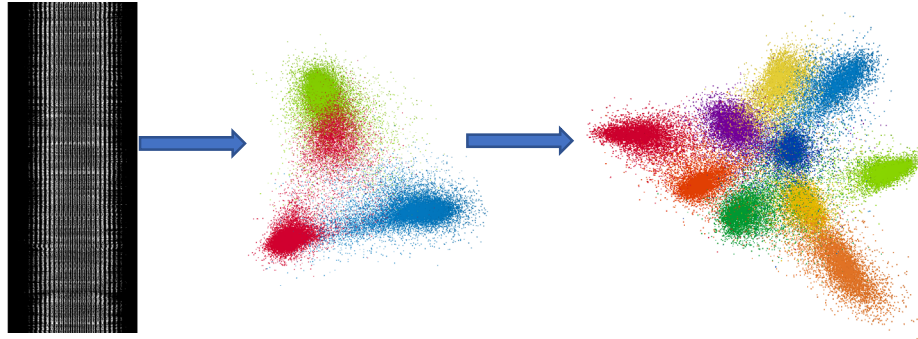
- Training Deep Learning requires vast numbers of finely labeled examples

- But humans need only a few examples ...



DEEP LEARNING WITH VISUAL INTERACTIONS

- Make the discovery of hidden groups/labels easier
- Generate semantic spatial representations of non-spatial high-dimensional data
- Combine the strengths of Humans and Deep Learning to refine and enhance the other for iterative discovery

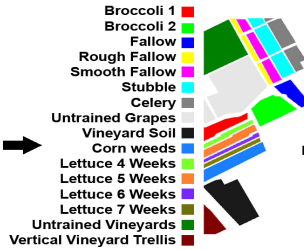


Traditional Deep Learning

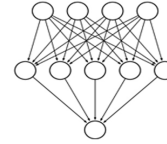
High-Dimensional Dataset



Manually Intensive Labeling



Deep Learning



Visually-Driven Interactive Deep Learning

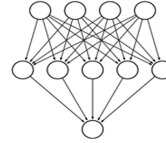
High-Dimensional Dataset



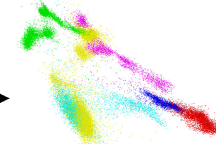
Manually Superficial Labeling



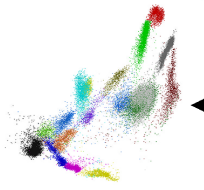
Deep Learning



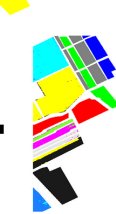
Visual Feature Representation



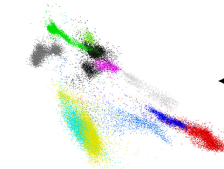
- Broccoli 1
- Broccoli 2
- Fallow
- Rough Fallow
- Smooth Fallow
- Stubble
- Celery
- Untrained Grapes
- Vineyard Soil
- Corn weeds
- Lettuce 4 Weeks
- Lettuce 5 Weeks
- Lettuce 6 Weeks
- Lettuce 7 Weeks
- Untrained Vineyards
- Vertical Vineyard Trellis



Discovered latent labels and semantic structure



Finer Labels



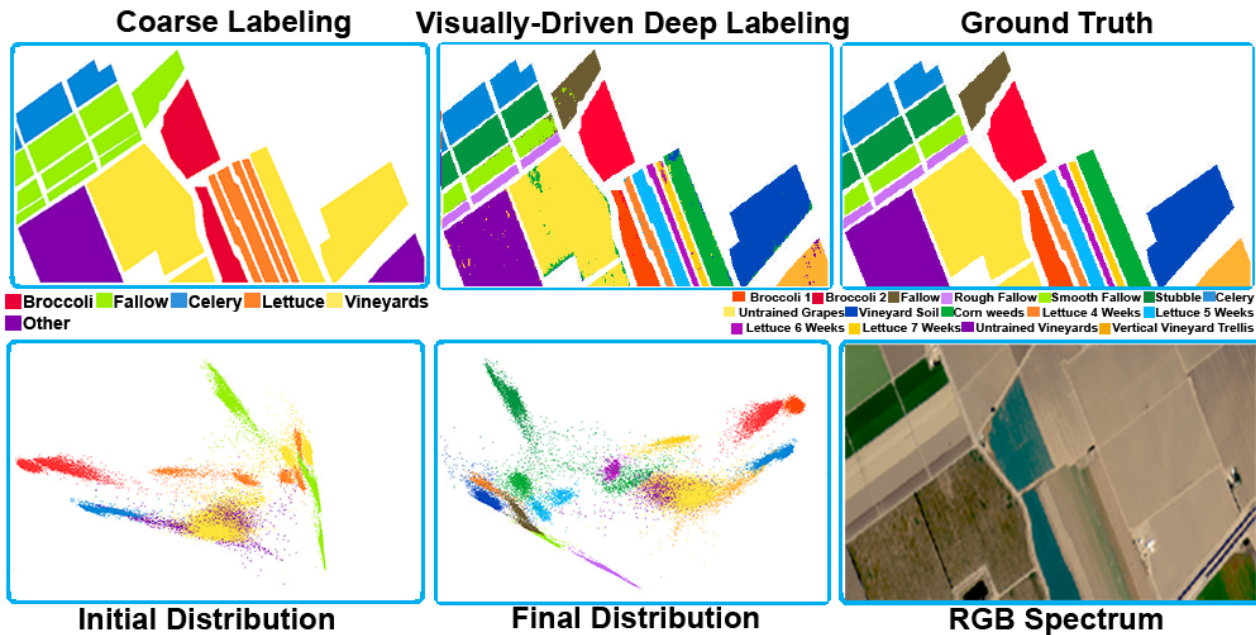
Human Refined Labeling



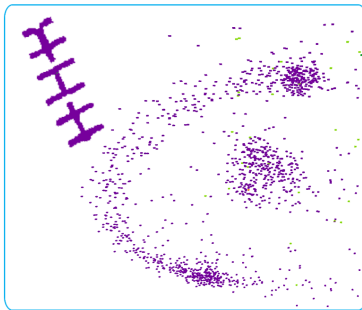
Human Interaction

RESULTS FOR HYPERSPPECTRAL DATA

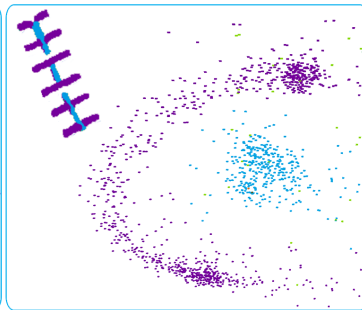
- Salinas Valley dataset, 512 x 217 image with 224 bands
- Generated 16 labels from 6 initial labels
- Reconstructed Accuracy of 97.4% in 5 iterations



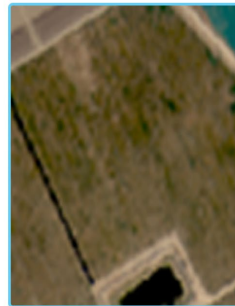
UNEXPECTED INSIGHTS



Before Labeling



After Labeling



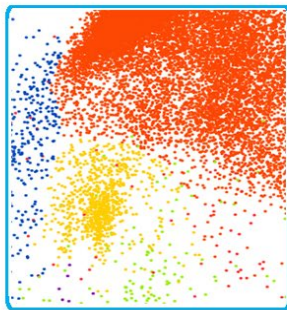
Aerial View



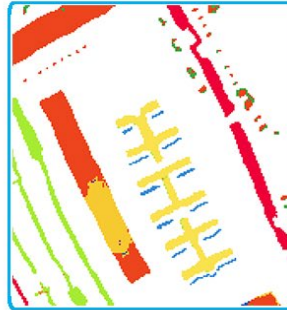
**Visually-Refined
Deep Labeling**



**Ground-Truth
Labeling**



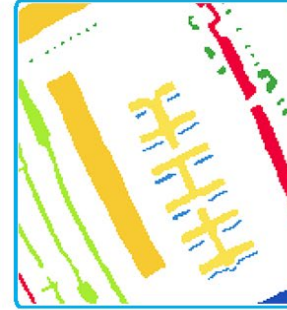
**2D Point
Distribution**



**Visually-Refined
Deep Labeling**



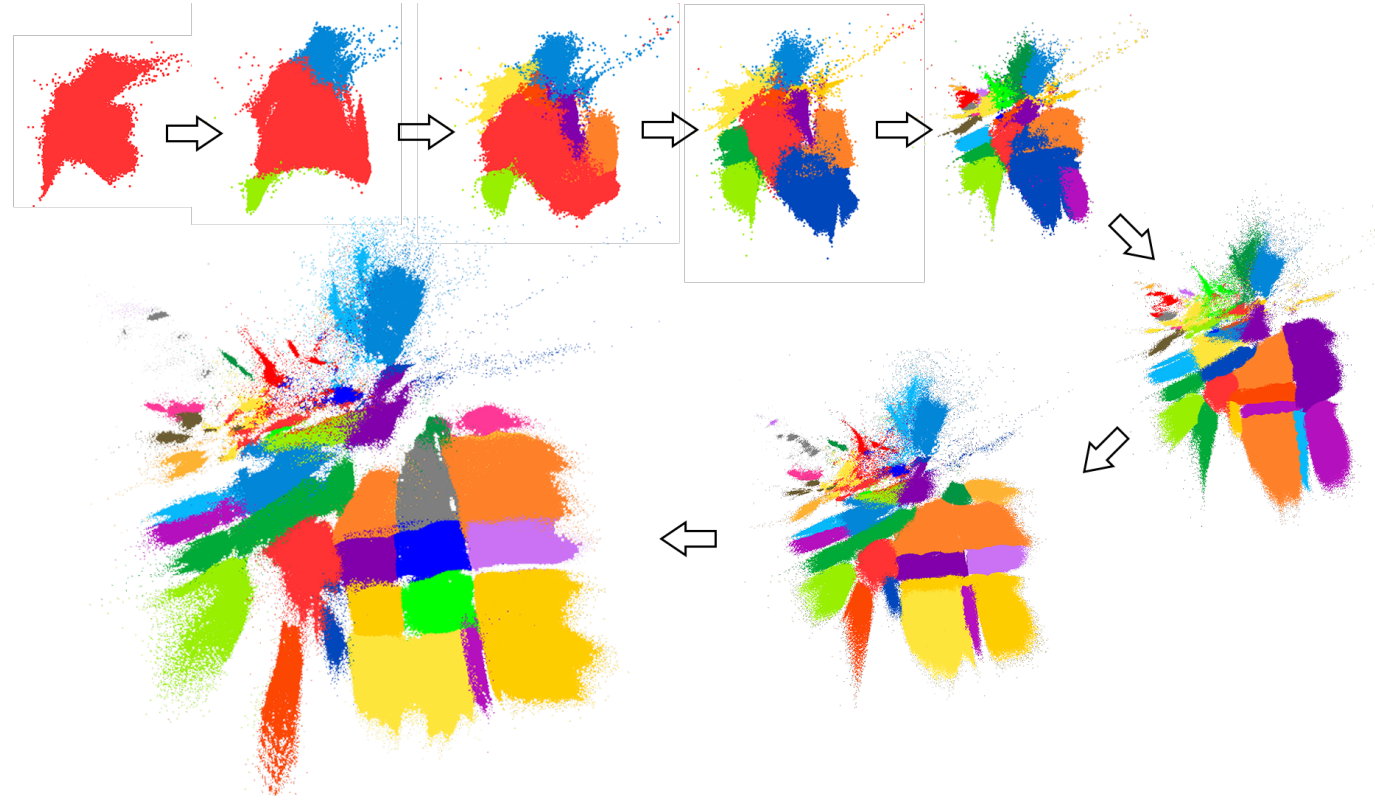
Aerial View



**Ground Truth
Labeling**

DNS QUERY DATASET

- 7 Million Query Points

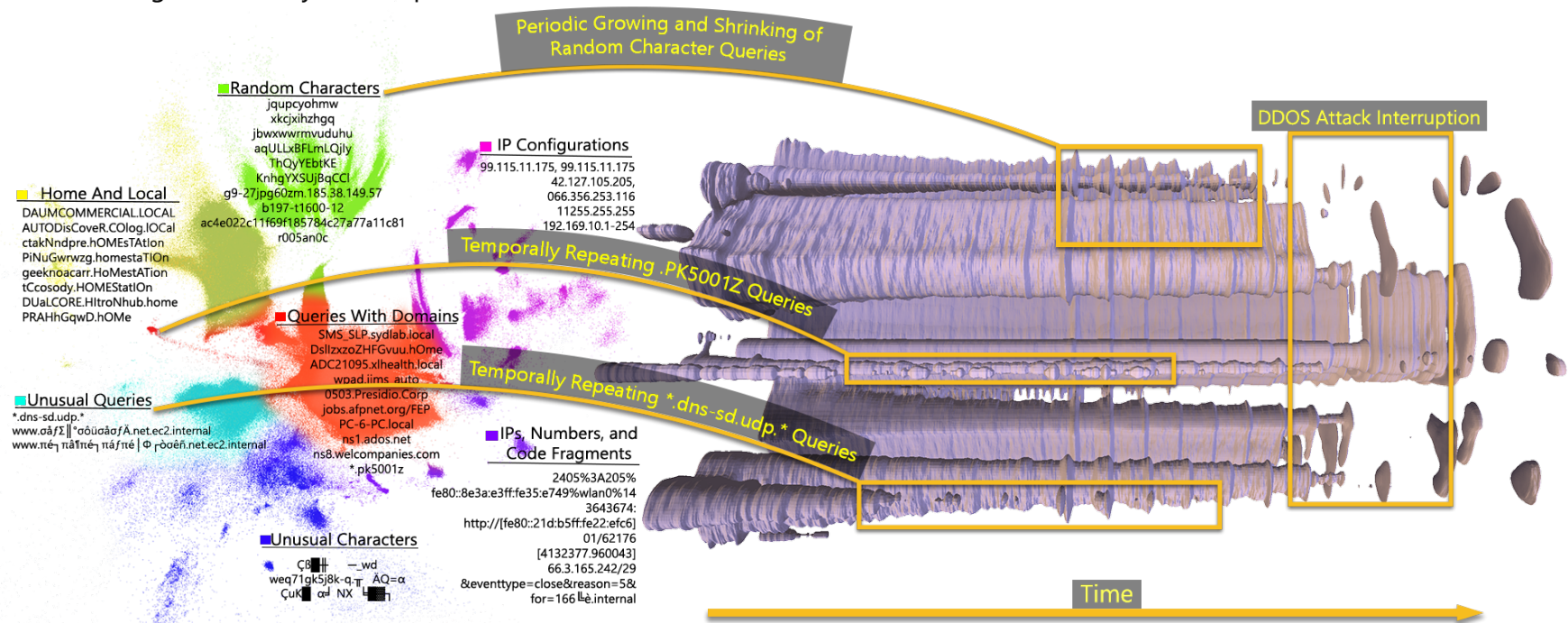


- We start with no labeling of queries

SPATIO-TEMPORAL DNS QUERY VISUALIZATION

Categorized Query Latent Space

3D Spatiotemporal Query Space



STAR MAPS



AUGMENTED REALITY STAR MAPS



Star Chart App

ObservEtoiles Planetarium at the Au Diable Vert in Glen Sutton, Quebec, Canada

CLOSING REMARKS

Exchange of ideas across traditional discipline boundaries
stimulating – *driving applications approach*

Critical to leverage human cognitive and perceptual skills in
visual computing

Incredible advances in Big Data, Machine Learning, Visual
computing in just the last 5 years; very exciting times ahead!



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