What's New in Radiance for 2016?

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Anyhere Software

Bug Fixes & Related

* Fixed slow-to-quit **rvu** and **rholo** when run in multi-processing mode
* File names may now be quoted in **rfluxmtx** (e.g., out="this file")
* Increased **rcontrib** max. modifier count to 10,000 (was 2048)
* Fixed **pkgBSDF** issue with -Z systems

Contributions

* Roland Schregle completed development of "out-of-core" photon mapping
* Jan Wienold updated evalglare to 1.30

Feature Additions

* Added mouse-wheel zoom to glrad
* Added "-in N" and "-on N" options to rcalc, rlam, and total
* New ability to handle CIE-XYZ (colorimetry) data in measured BSDFs
    * Added pabopto2xyz tool to assist

Added Mouse-wheel Zoom to glrad

* glrad — what's that, again?
* wasn't working anymore, because of window resizing changes
* mouse-wheel input now recognized and used to control zoom in/out

rvu vs. glrad

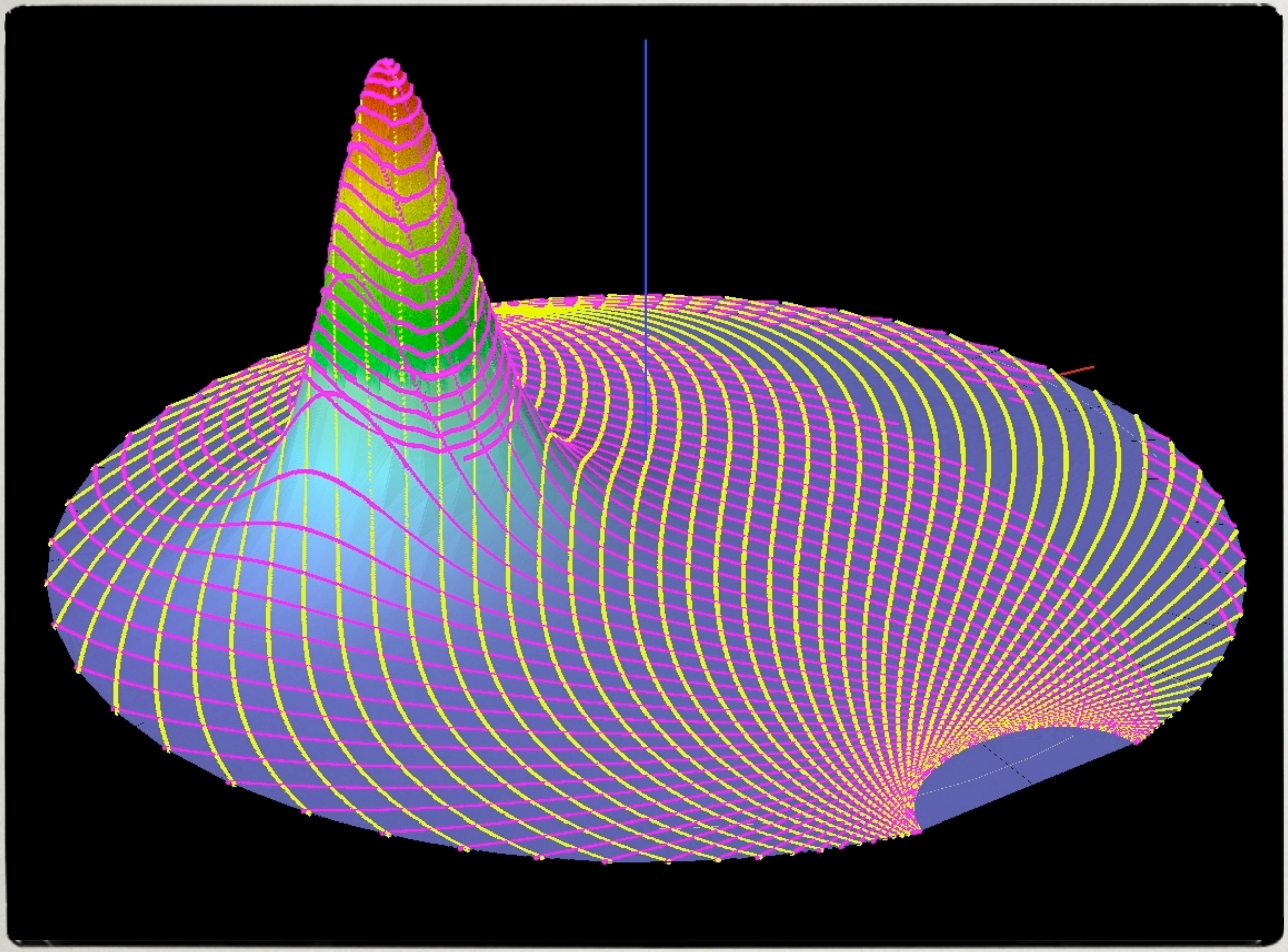
New -in N and -on N options for rcalc, etc.

* Legend has it that binary record counts are unreliable under Windows
* Schorsch insists this hasn't been a problem for ages
* Piped commands with binary data still cause problems, so this may resolve it

CIE-XYZ Colorimetry in BSDF measurements

* Previously added colorimetry support to genBSDF, XML specs and rendering
* Still, we had no way to go from measurements to XML representation
* Added CIE-XYZ to interpolation code (pabopto2bsdf) and converters (bsdf2klems & bsdf2ttree)

First, let's do a little review...

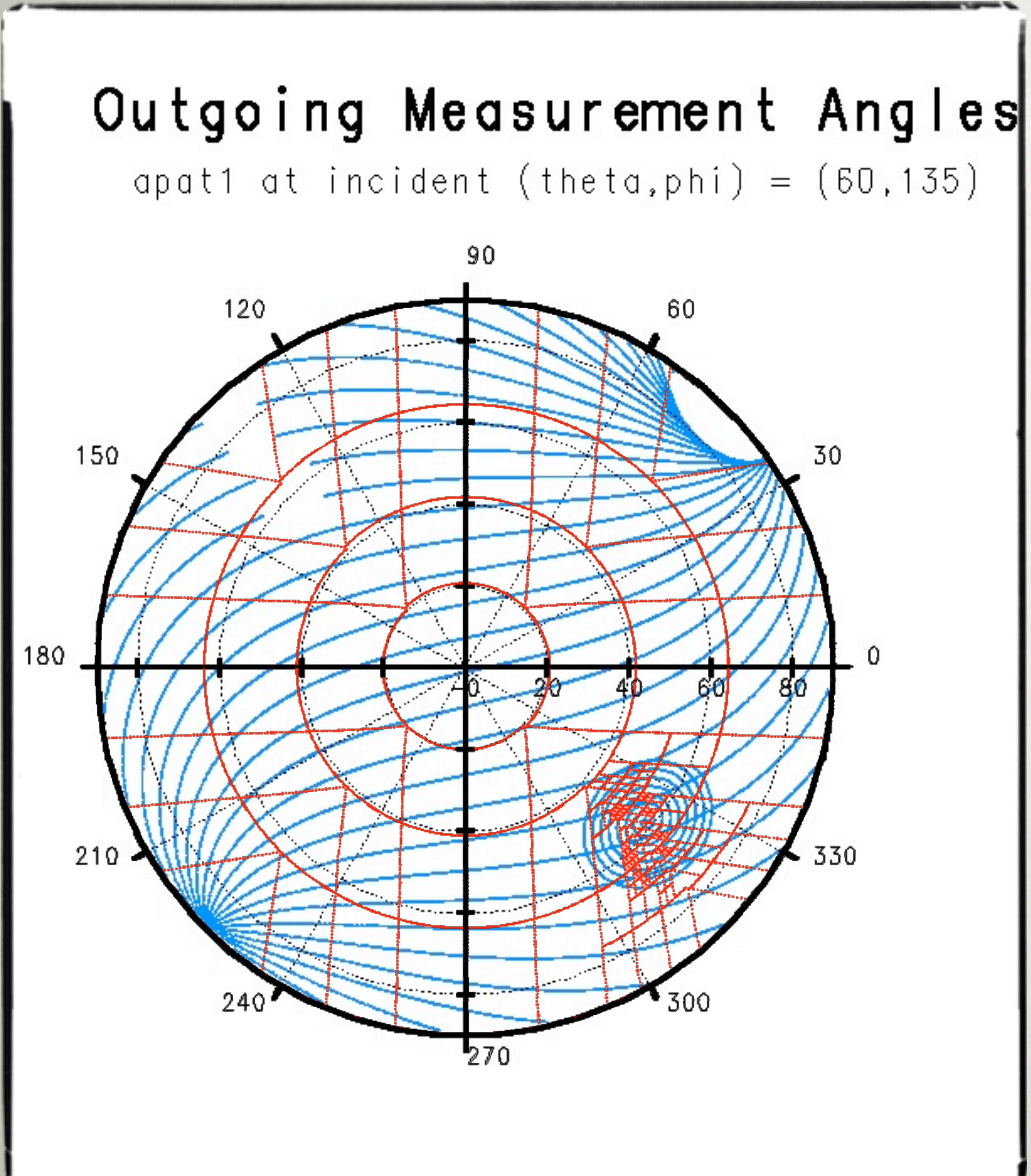


Measured BRDF

Aluminum sawtooth profile
(one incident direction shown)

The Interpolation Problem in Parts

A. Interpolate exiting BSDF measurements
B. Order incident directions into mesh
C. Energy displacement interpolation
D. Account for BSDF symmetry



A. Interpolate Exiting BSDF Measurements

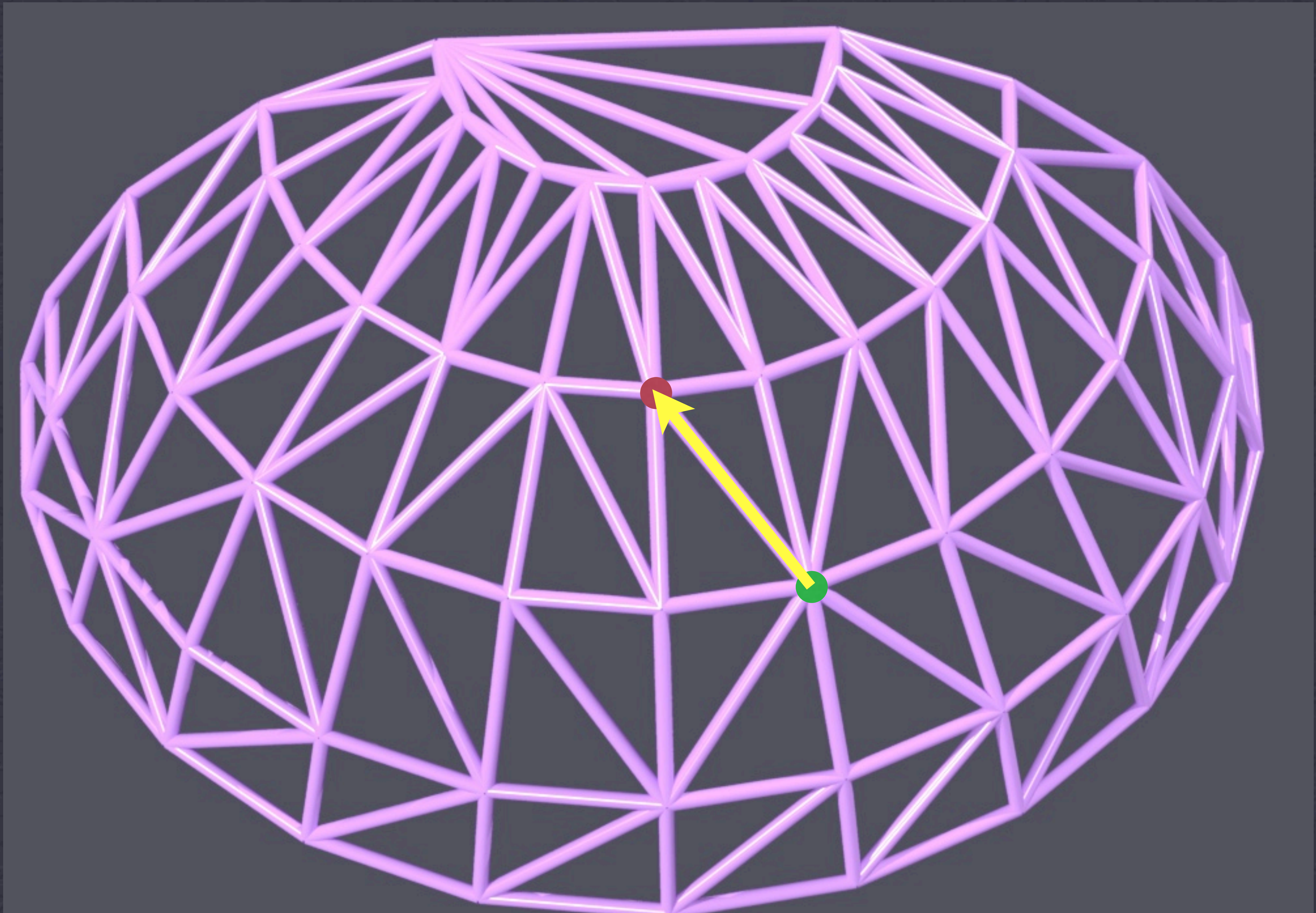
Typical measurement pattern, showing dense points along scan paths but missing retro-reflection data. Includes high-resolution secondary spiral about mirror direction.

Quadtree subdivides data such that every leaf has at least one measurement and uniform areas are combined into larger regions while maintaining energy balance.

Quadtree leaves become Gaussian lobes that sum to an outgoing *Radial Basis Function* for hemisphere

B. Order Incident Directions into Mesh

- Radial Basis Function interpolates outgoing values at one incident angle
- We need to organize incident directions
- Create Delaunay mesh on appropriate section of incident hemisphere

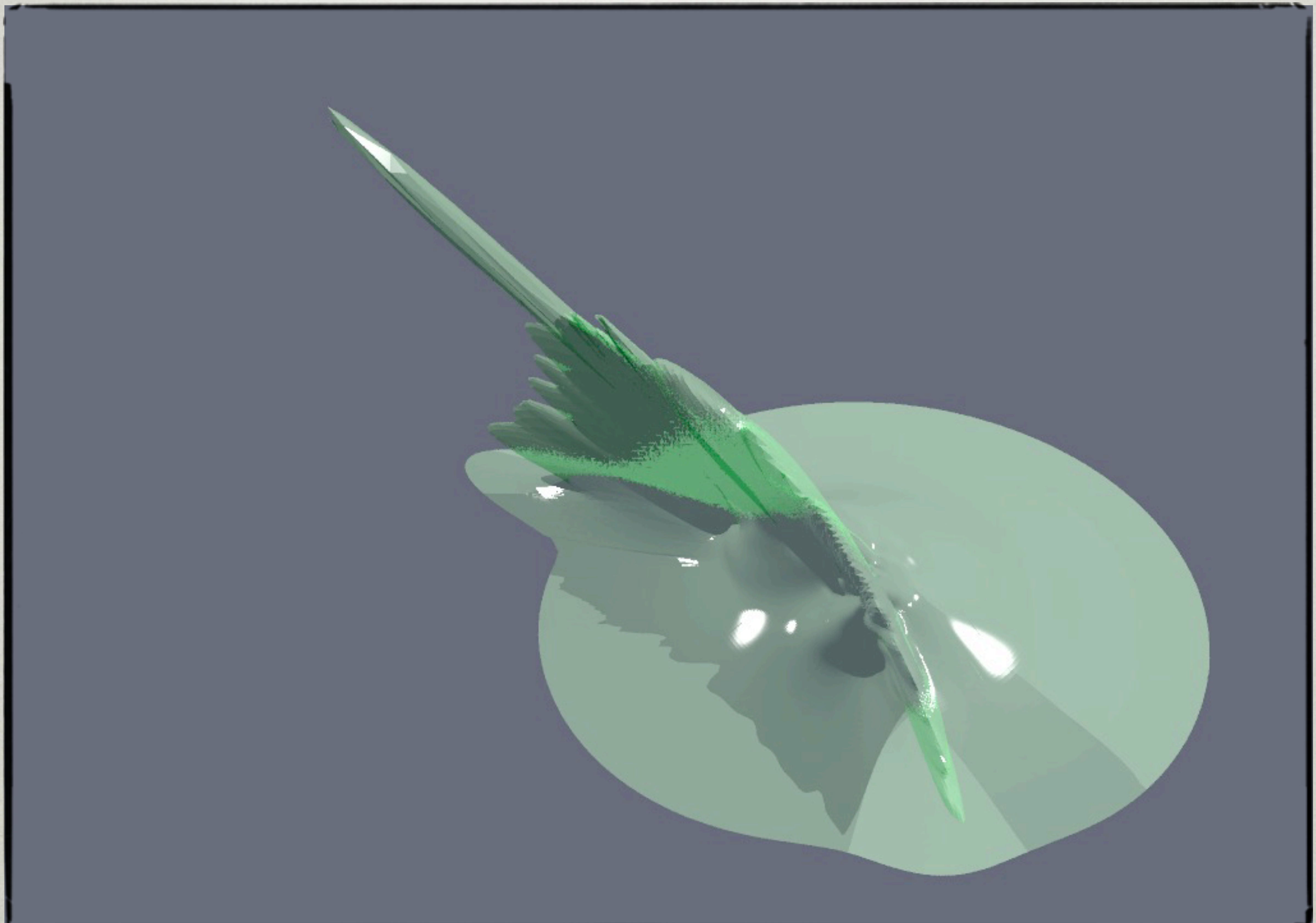


Example Incident Direction Mesh (bilateral symmetry)

Delaunay triangulation on hemisphere — each vertex represents Radial Basis Function

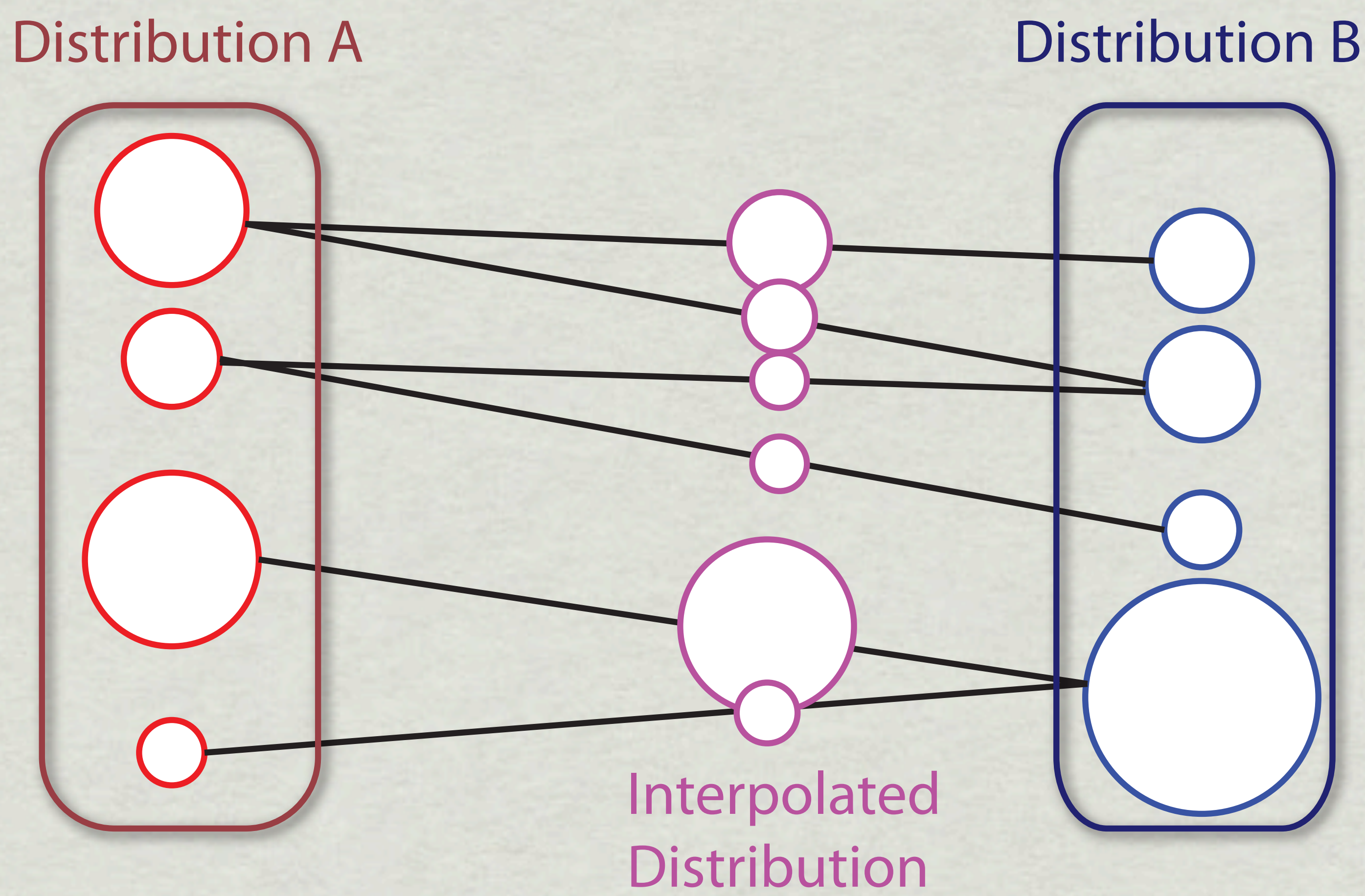
C. Energy Displacement Interpolation

- Most interpolation methods result in odd lobe disappearance/reappearance
- Key insight taken from 2011 SIGGRAPH Asia paper by Bonneel, van de Panne, Paris, & Heidrich
- Use Lagrangian mass transport and minimize Earth mover's distance



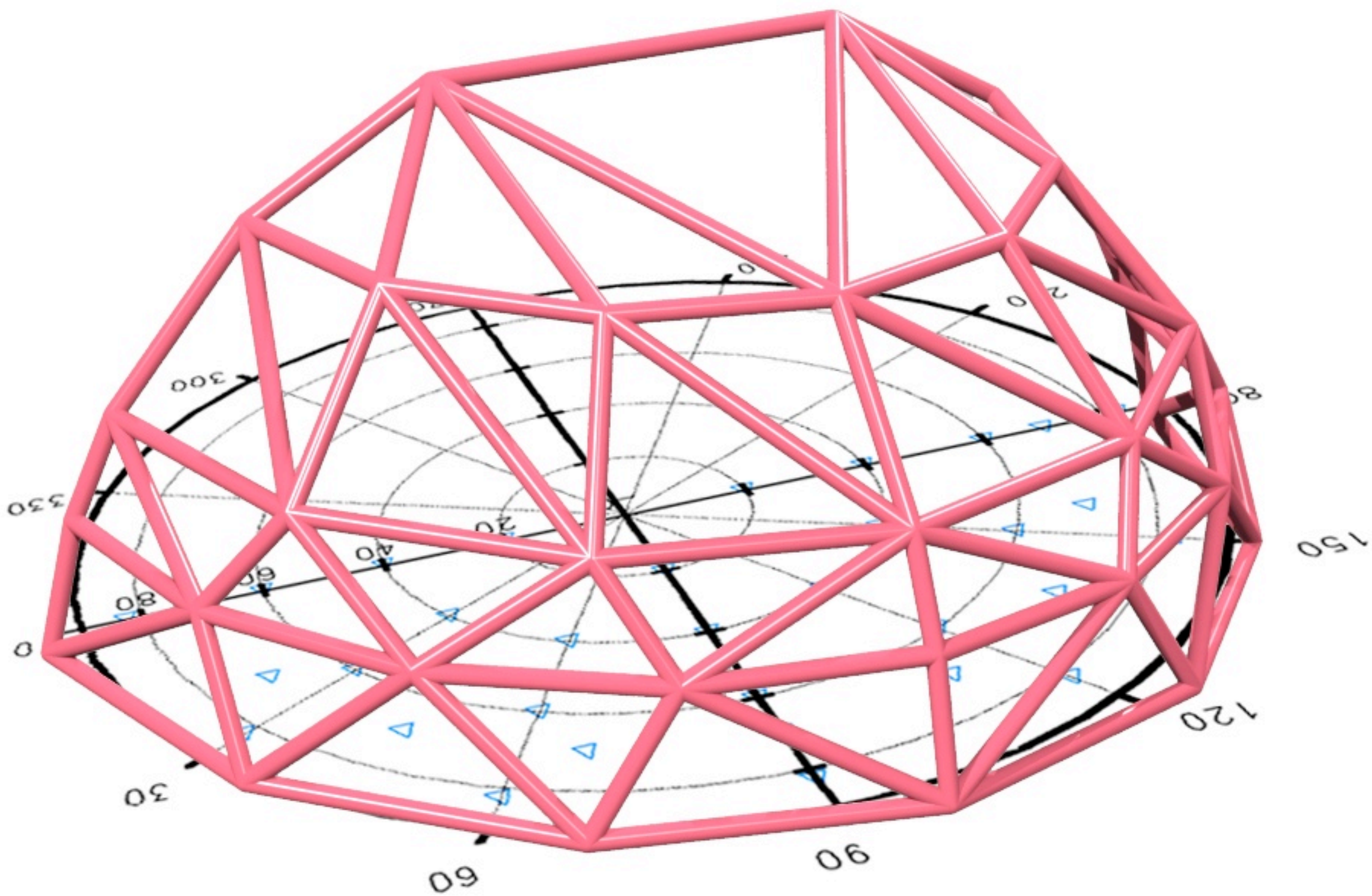
Linear Interpolation of Incident Angles

Advection and EMD



- Earth Mover's Distance minimizes cost of migration matrix **M**
- Source (A) and destination (B) distributions typically have a different number of lobes
- Interpolated distribution usually has more than either A or B

Advection in Triangle



Advection in Triangle

$$\sigma(s,t) = \sqrt{(1-t)((1-s){\sigma_a^i}^2 + s{\sigma_b^j}^2) + t{\sigma_c^k}^2},$$

$$\alpha(s,t) = \alpha_a^i \cdot M_{ab}^{ij} \cdot [(1-s) \cdot M_{ac}^{ik} \cdot (1 - t + t \cdot \frac{E^k}{E^i}),$$

$$+ s \cdot \frac{E^j}{E^i} \cdot M_{bc}^{jk} \cdot (1 - t + t \cdot \frac{E^k}{E^j})] \cdot \frac{{\sigma_a^i}^2}{\sigma(s,t)^2},$$

$$\mu(s,t) = \mathrm{Slerp}(\mathrm{Slerp}(\mu_a^i, s, \mu_b^j), t, \mu_c^k),$$

σ's are lobe standard deviations

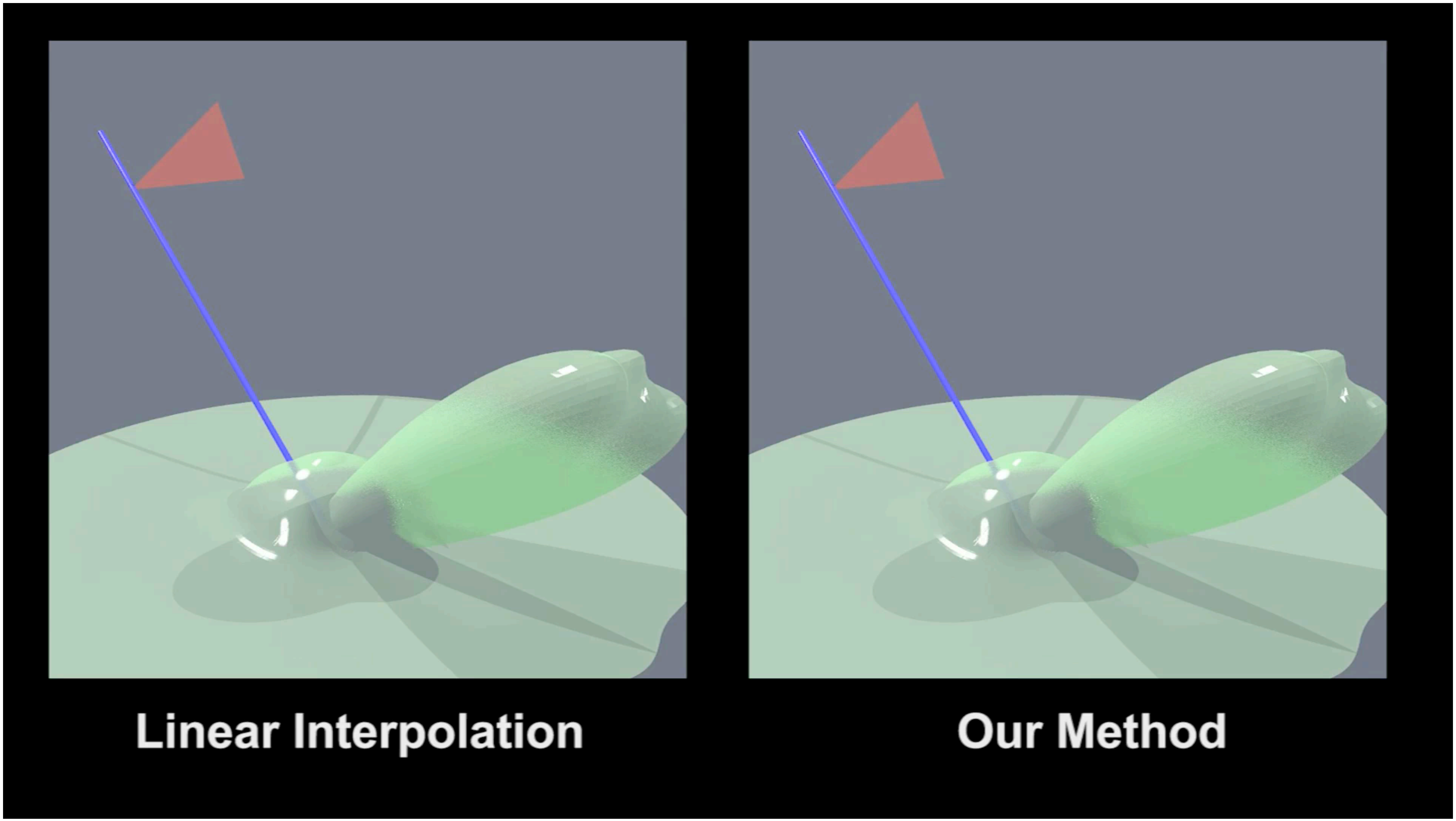
α's are lobe amplitudes

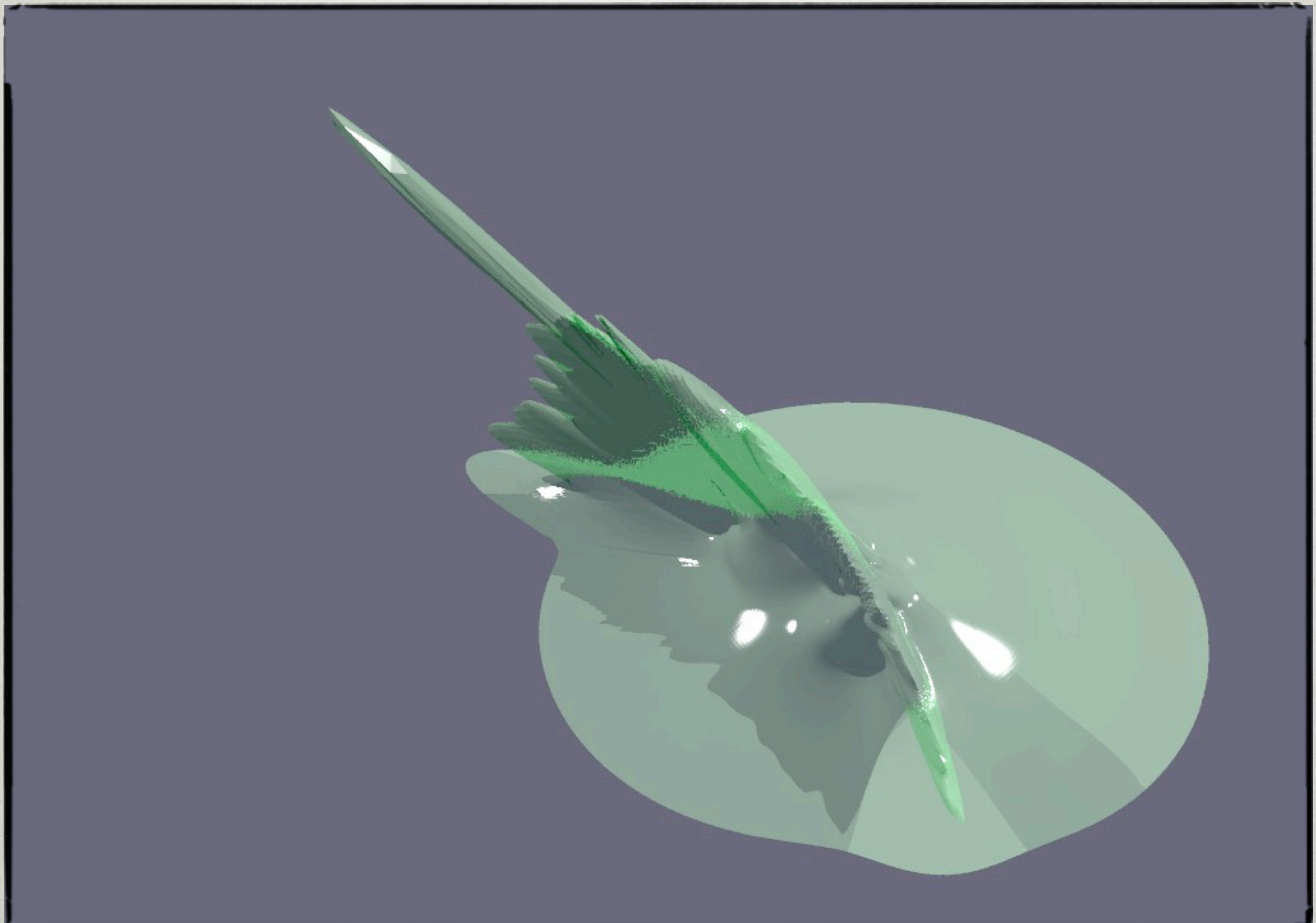
μ's are lobe directions

E's are input distribution energies

M's are migration matrix coefficients

Side-by-Side Comparison

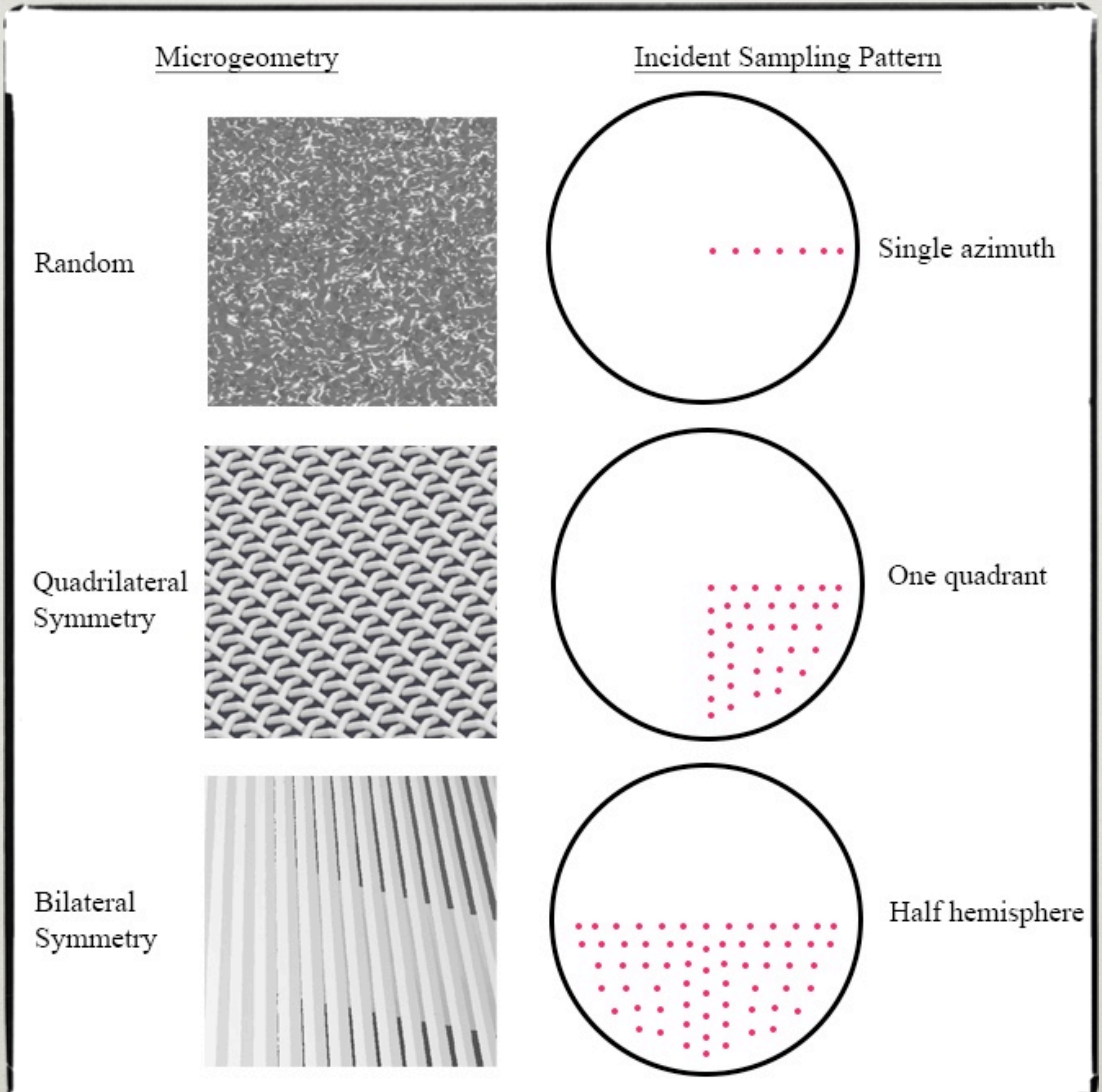




Advection of Incident Angles

D. Account for BSDF Symmetry

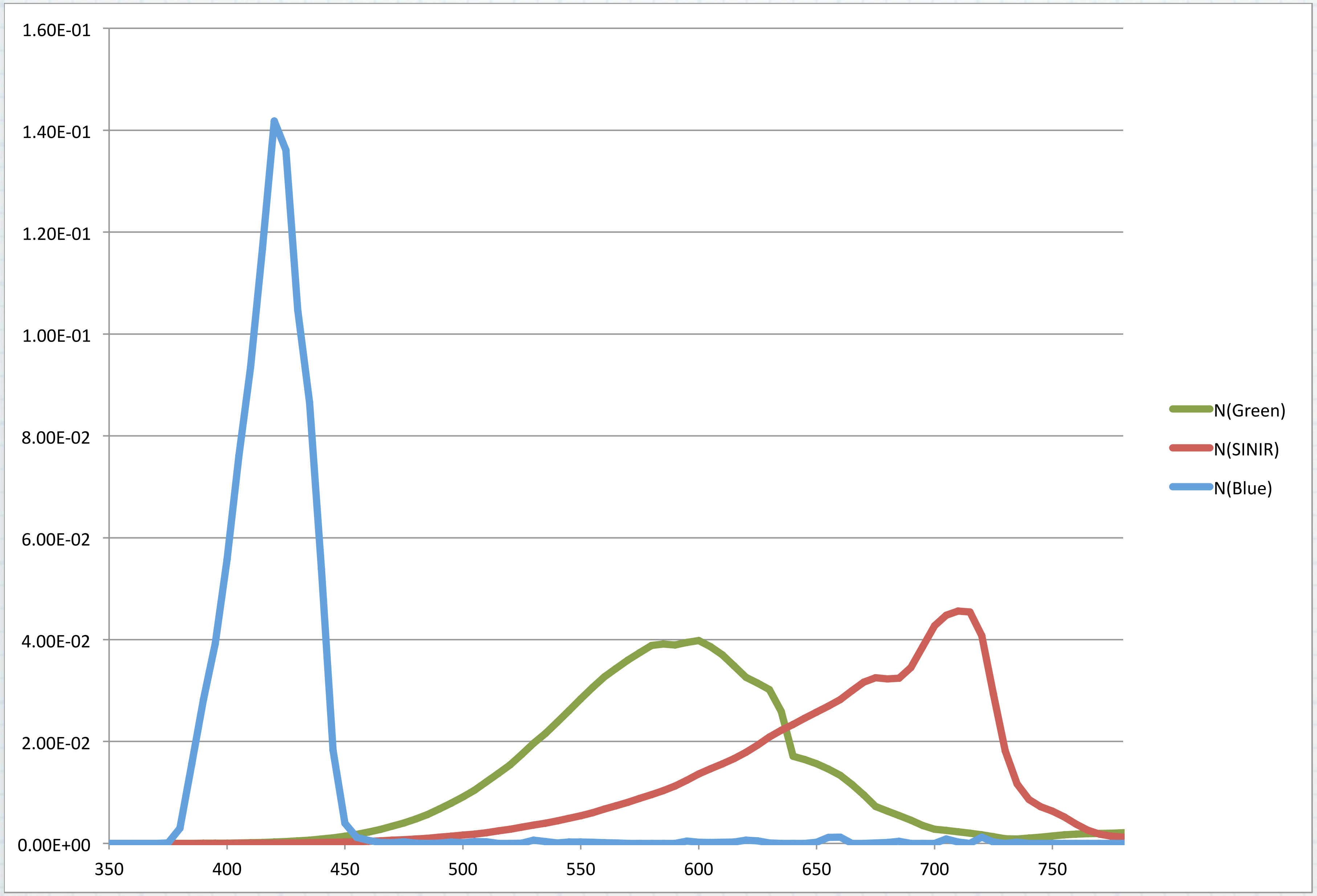
- Most BSDFs exhibit symmetry based on construction or microgeometry
- Gonioreflectometer operator uses knowledge to skip redundant directions
- We can deduce symmetry (& isotropy) from measurements taken
- Fill hemisphere by reflection/rotation


Microgeometry
Incident Sampling Pattern
Random
Single azimuth
Quadrilateral Symmetry
One quadrant
Bilateral Symmetry
Half hemisphere

BSDF Colorimetry

* Digesting spectral channels separately causes problems during interpolation
    * i.e., chromatic errors in highlights
* Full spectral simulation is future work
* Created pabopto2xyz to combine measured spectral sensitivities into coincident CIE-XYZ samples

Example Spectral Sensitivity Curves



Corresponding Color Conversion Matrix

$$
\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.875 & 0.035 & 0.09 \\ 1.346 & -0.391 & 0.073 \\ 0.273 & -0.211 & 1.101 \end{bmatrix} \begin{bmatrix} G \\ R \\ B \end{bmatrix}
$$

Calculated from 24 Macbeth ColorChecker™ patches

New pabopto2xyz tool

* Takes 3 sets of BSDF measurements in Mountain format, one set per channel
  * assumes each incidence repeated/chan
  * also specify XYZ conversion matrix
* Interpolates & writes XYZ pseudo-measurements in Mountain+ format

Example Input/Output

Input per channel:

```
#data written using pabwritetxt
#integrated_value 0.11721
#incident_angle 50 0
#intheta 50
#inphi 0
#upphi 0
#datapoints_in_file: 236687
#format: theta phi DSF
49.741 177.901 5.517
49.744 177.902 5.515
49.747 177.901 5.51
...
```

Combined output:

```
#data written using pabopto2xyz
#incident_angle 50 0
#intheta 50
#inphi 0
#upphi 0
#colorimetry: CIE-XYZ
#datapoints_in_file: 236687
#format: theta phi DSF
49.741 177.901 5.5337 5.7099 6.5878
49.744 177.902 5.5317 5.7099 6.5887
49.747 177.901 5.5267 5.7041 6.5820
...
```

red & blue channels may have different datapoint count

The “Why” & the “How”

* It’s difficult/impossible to repeat measurement positions exactly
* Without coincident measurements, channel interpolations would split
* Interpolate new channels to coincide with Y-channel meas. positions

The "Why" & the "How"

* pabopto2xyz uses 2-D anisotropic Gaussian interpolation code (interp2d)
* More strict than radial basis function
* Code is working, at least mechanically
* Need to test with more reliable data

Conclusions

* People always want you to conclude something
* Conclusions are often meaningless
* Thankfully, I've just about used up the space on this slide
* Any questions or suggestions?