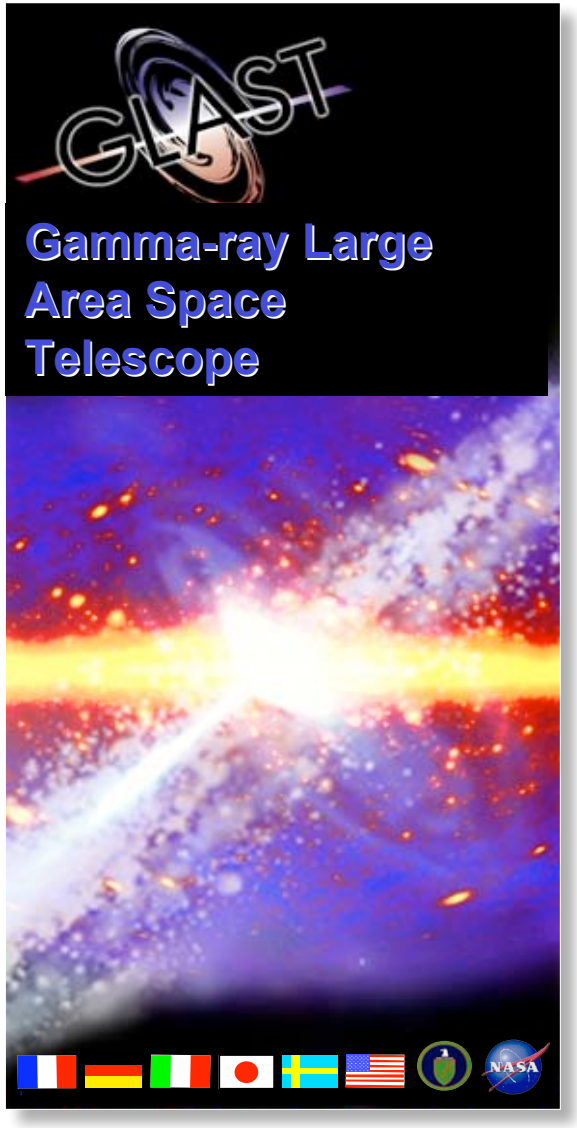



# Photon Event Maps

- Source Detection
- Transient Detection

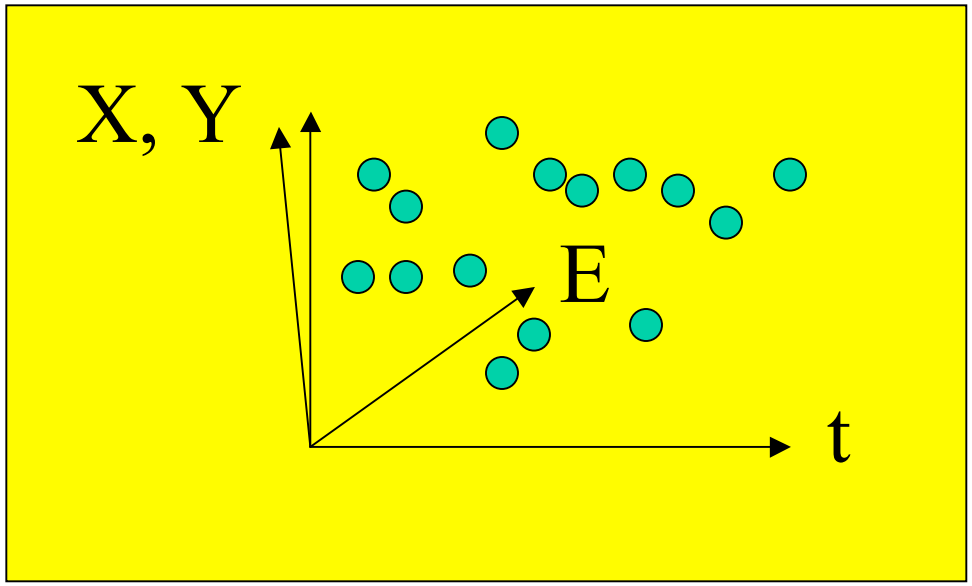
Jeff Scargle
Space Science Division
NASA Ames Research Center

Thanks: Jay Norris, and AISRP

# The GLAST Data Stream

4-Dimensional Data Space:

- position on the sky
- time of arrival
- energy




$$\{ X_i , Y_i , t_i , E_i ; i = 1, 2, 3, \ldots N \}$$

# Density Estimation + Structure Identification

Many analysis problems can be treated with a two-step procedure:

- Estimate photon density in the data space
- Identify and characterize structures in the density profile

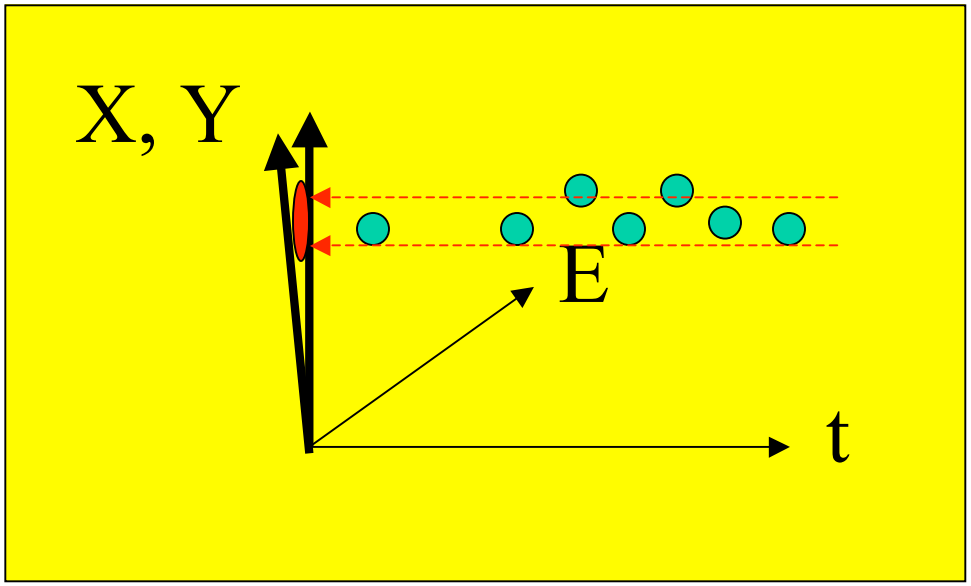
Photon density estimates radiation intensity.

# Density Estimation + Structure Identification

Many analysis problems can be treated with a two-step procedure:

- Estimate photon density in the data space
- Identify and characterize structures in the density profile

Example: Source Detection (point or Extended)

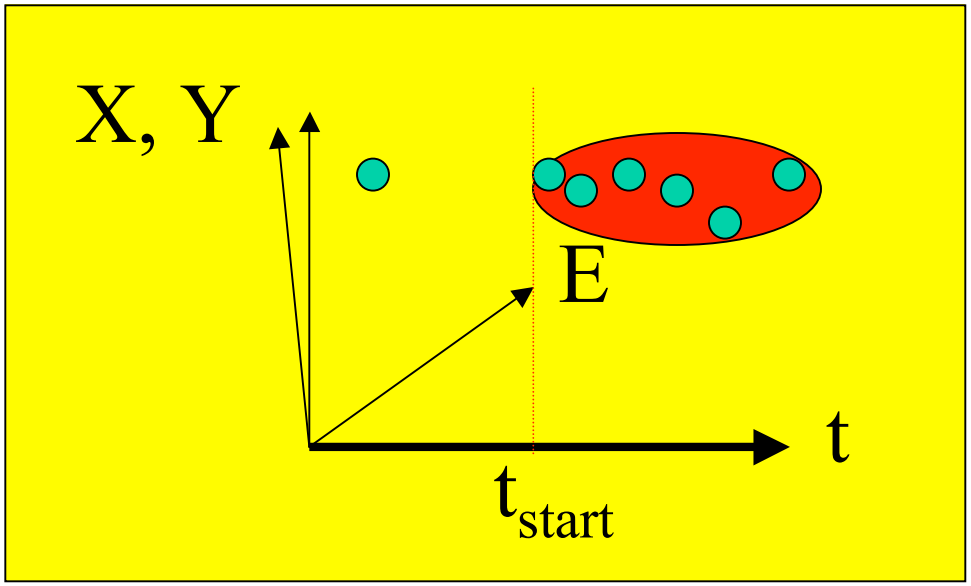


# Density Estimation + Structure Identification

Many analysis problems can be treated with a two-step procedure:

- Estimate photon density in the data space
- Identify and characterize structures in the density profile

Example: Transient Detection

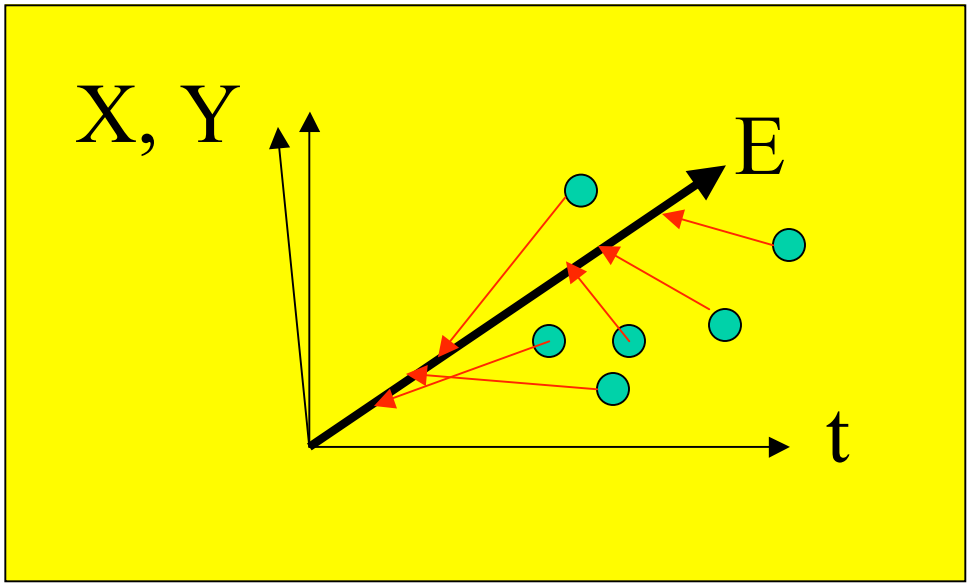


# Density Estimation + Structure Identification

Many analysis problems can be treated with a two-step procedure:

- Estimate photon density in the data space
- Identify and characterize structures in the density profile

Example: Spectrum Analysis






# The Bin Myths

I. Point data must be binned in order to make sense out of them.

II. The bins must be large enough so that each bin has a significantly large sample.

<u>The analysis described here uses no binning:</u>

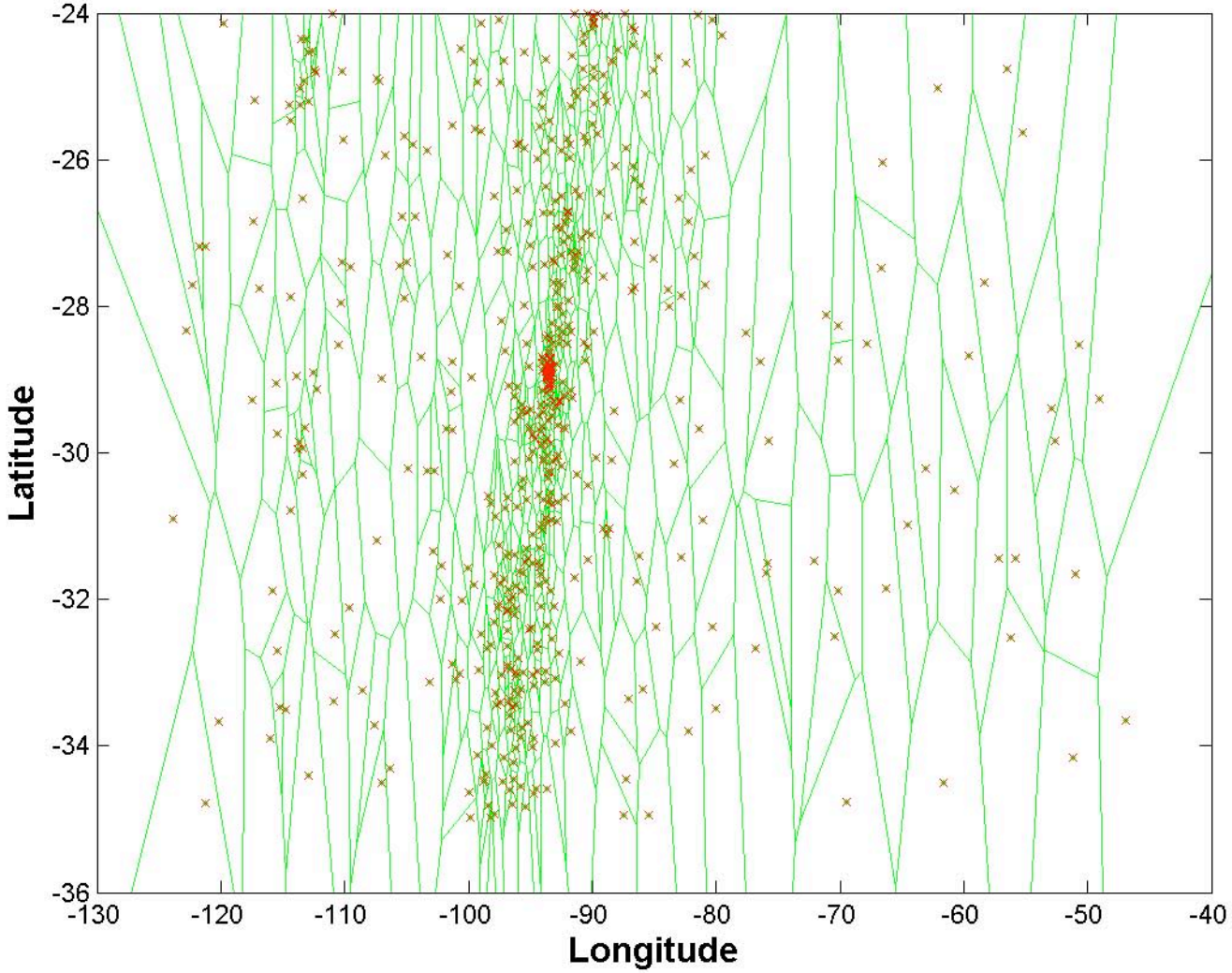
~~No spatial bins (healpix)~~

~~No spatial smoothing~~ (such as convolution with a kernel)

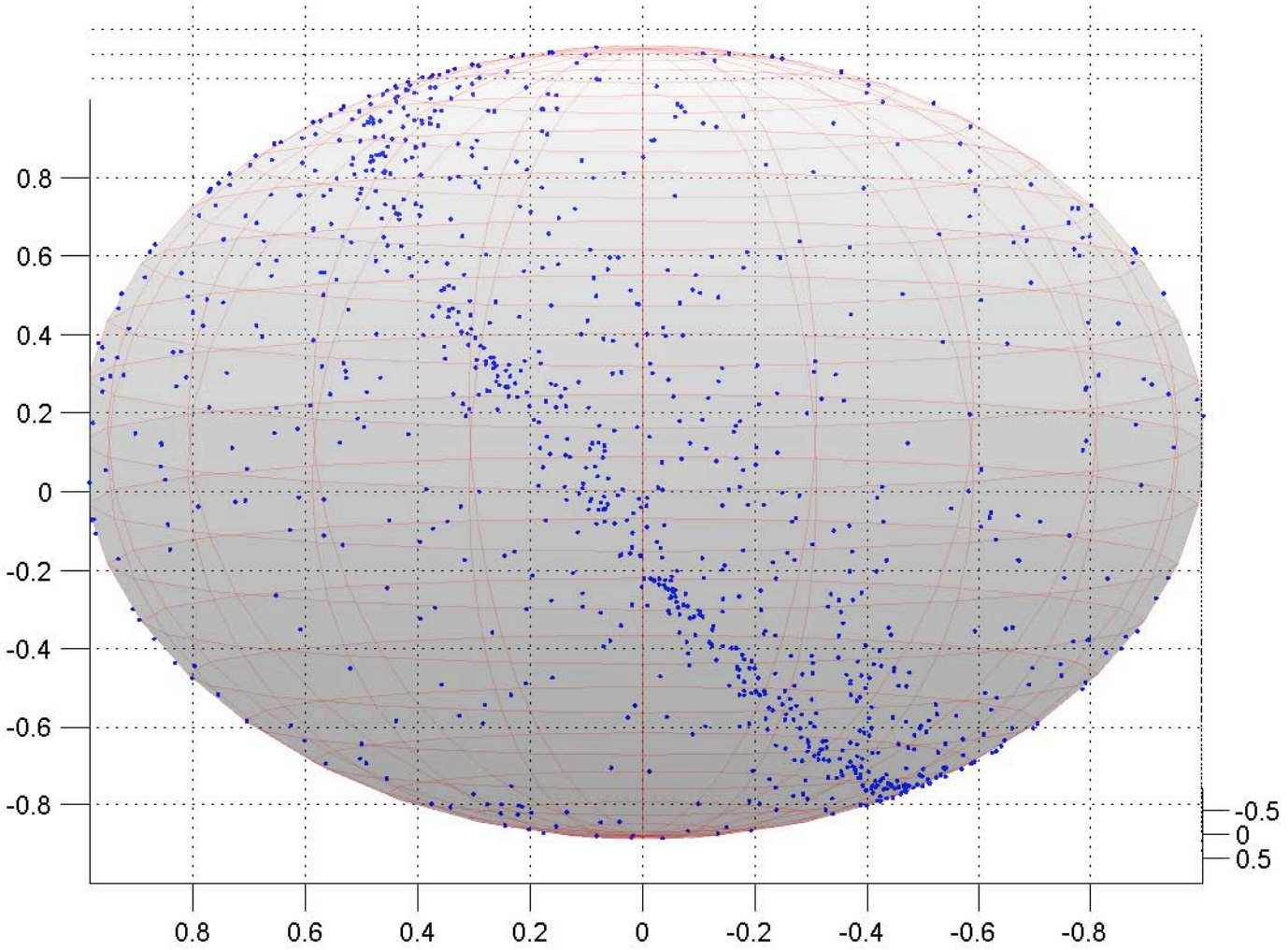
~~No sliding templates~~ (such as likelihood test statistic)

~~No time bins~~

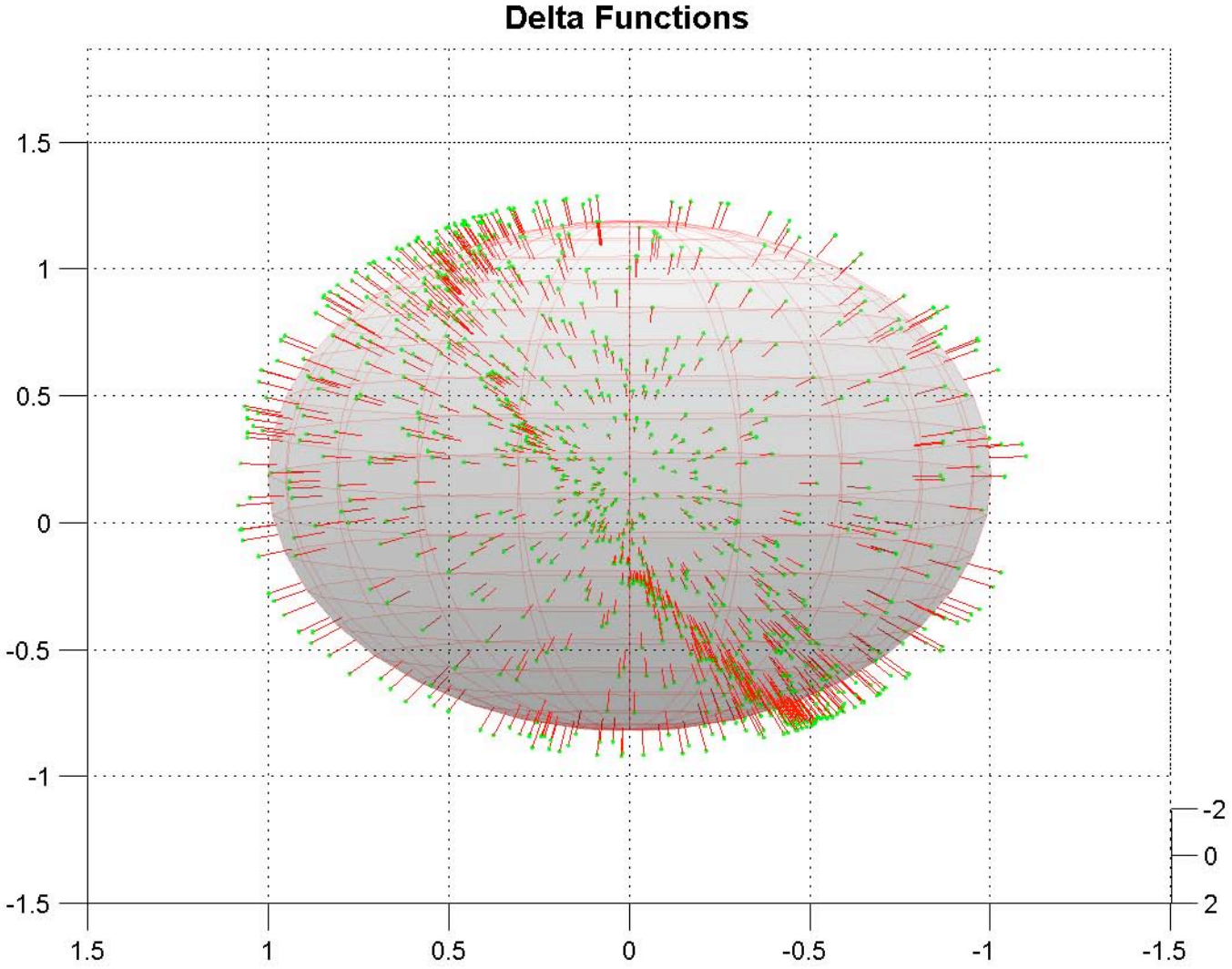
~~No energy bins~~


Latitude
Longitude
-24
-26
-28
-30
-32
-34
-36
-130
-120
-110
-100
-90
-80
-70
-60
-50
-40

# Photons on the Sphere



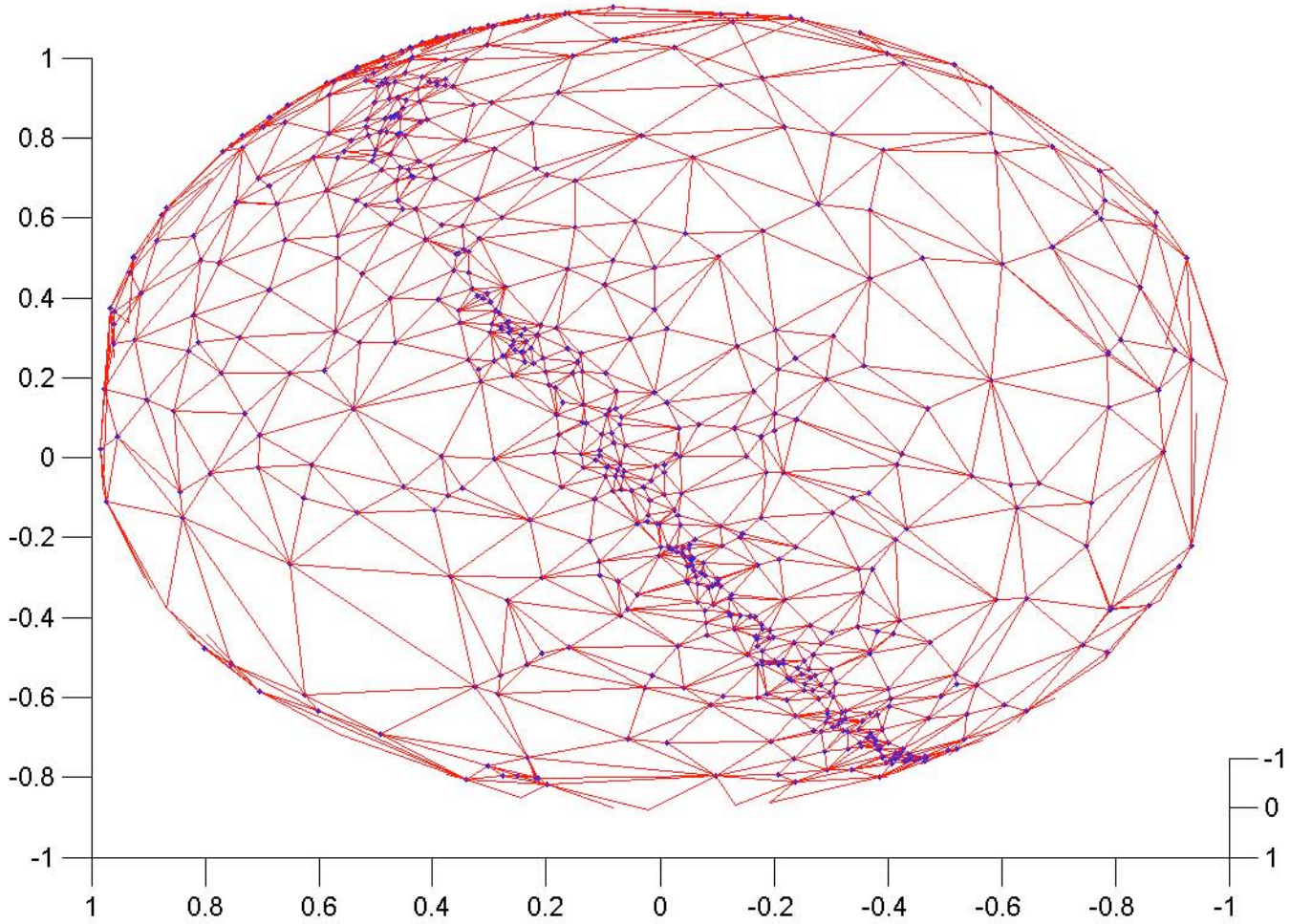
# Photons on the Sphere

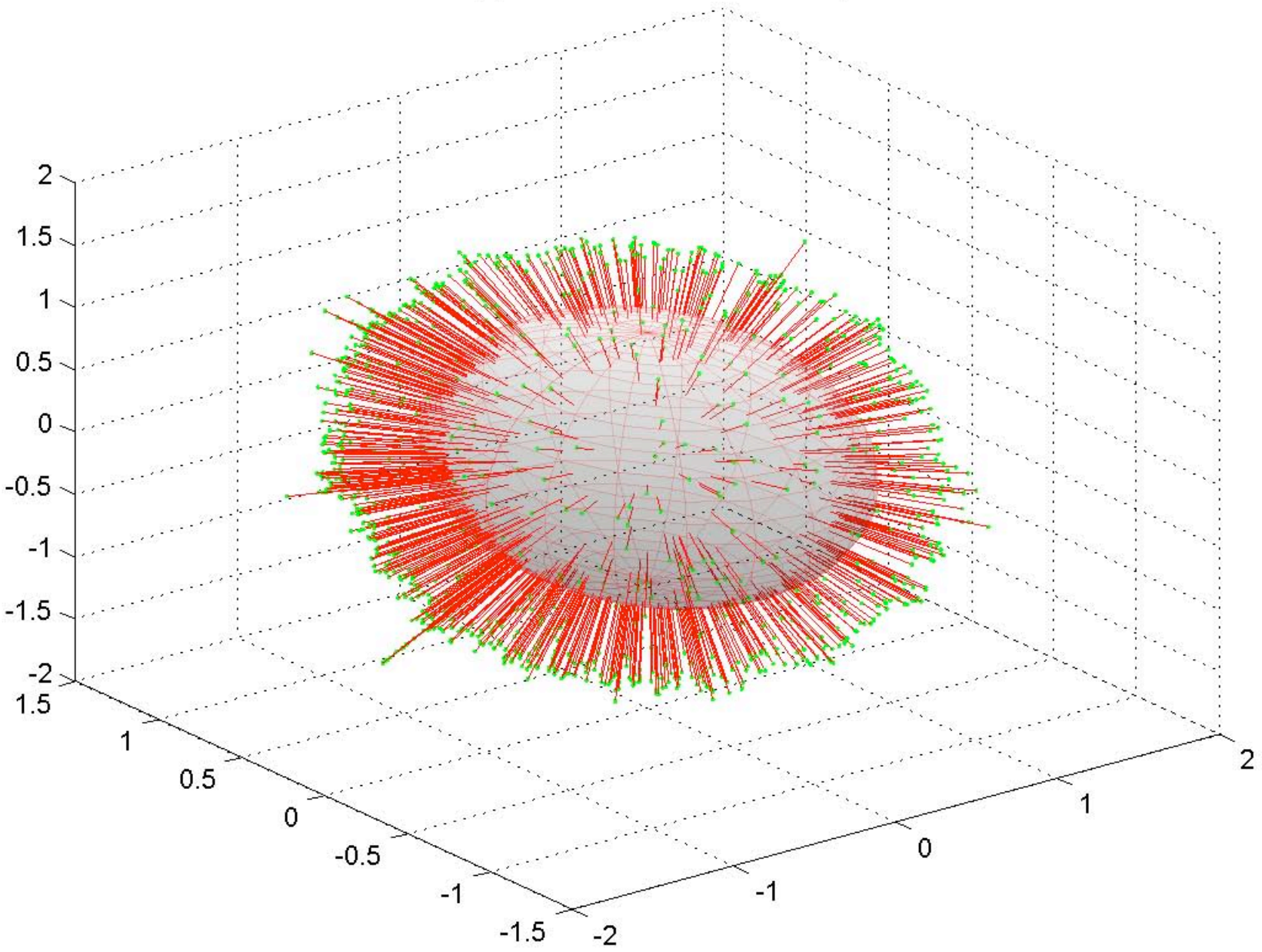


Jeff Scargle

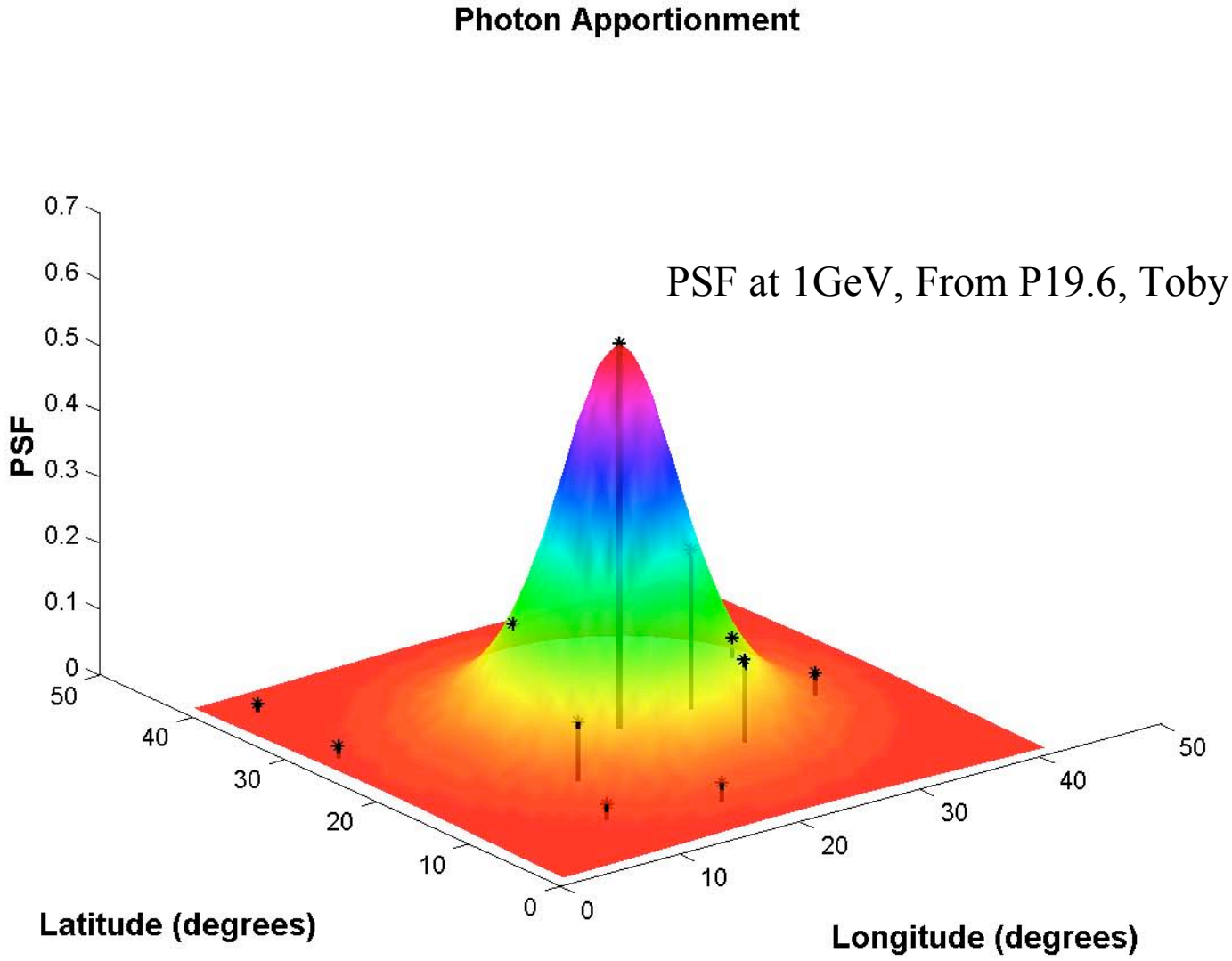
# Photons on the Sphere

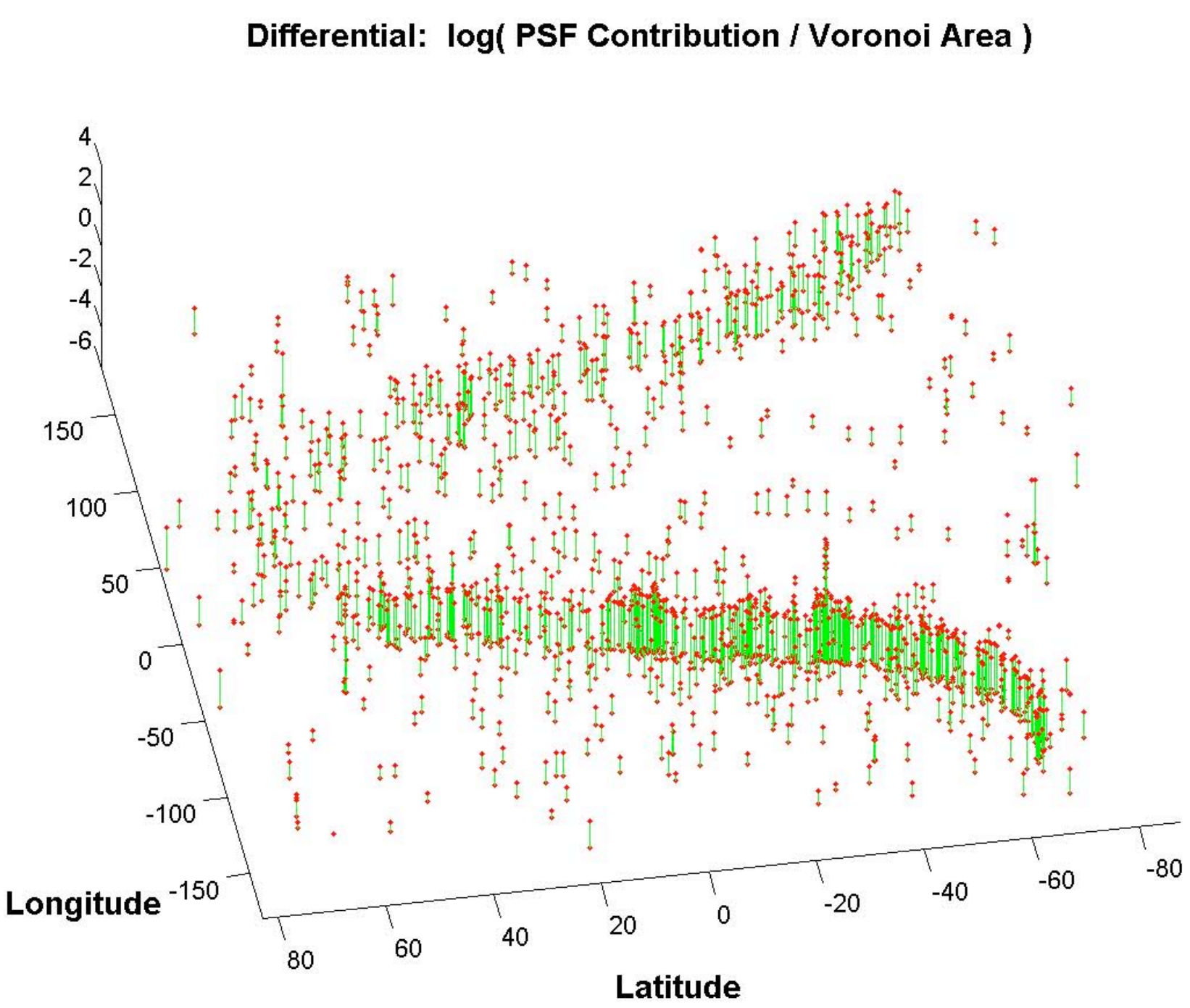
Photon positions on sphere → convex hull → Delaunay triangulation → Voronoi tessellation

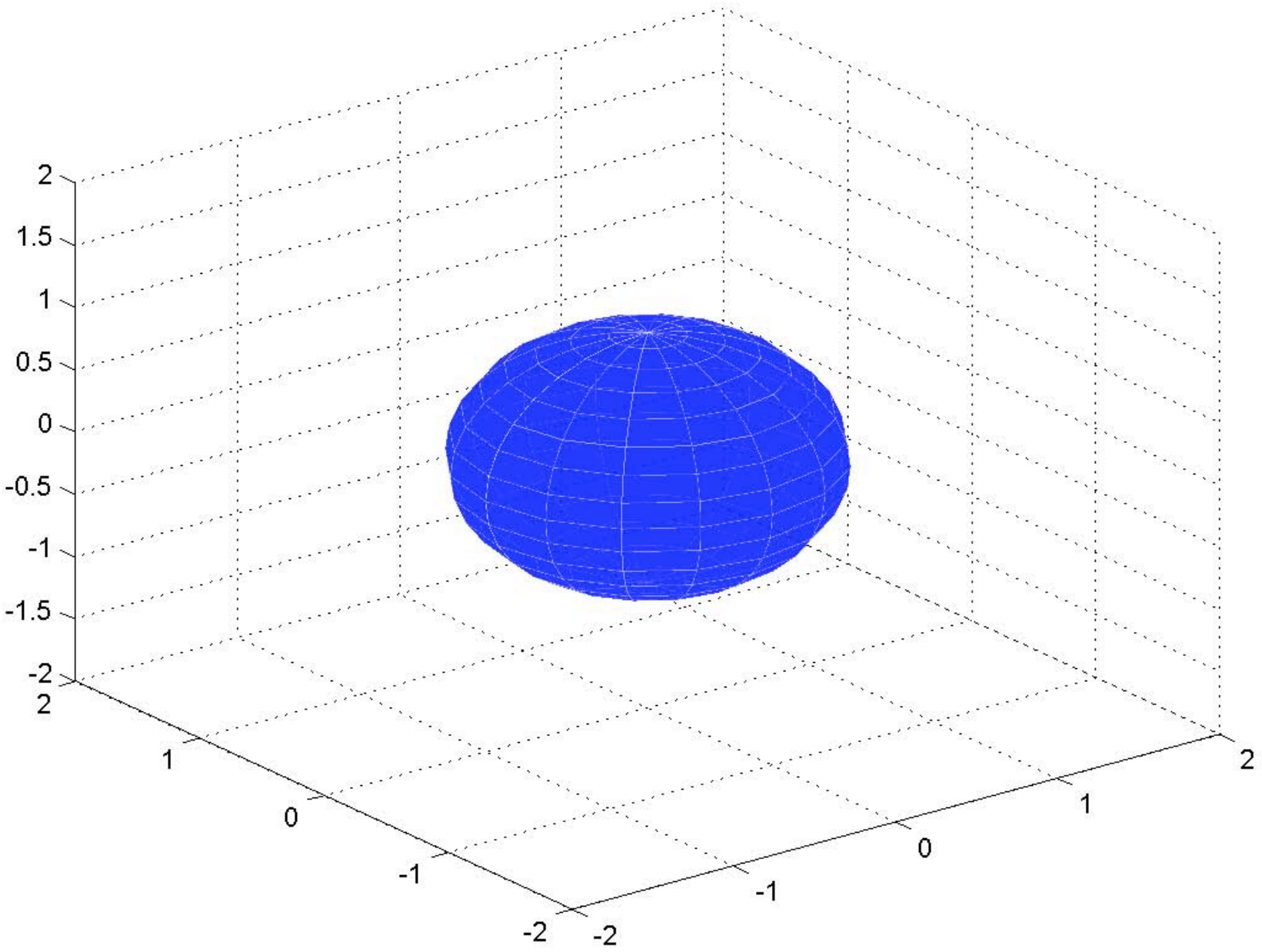


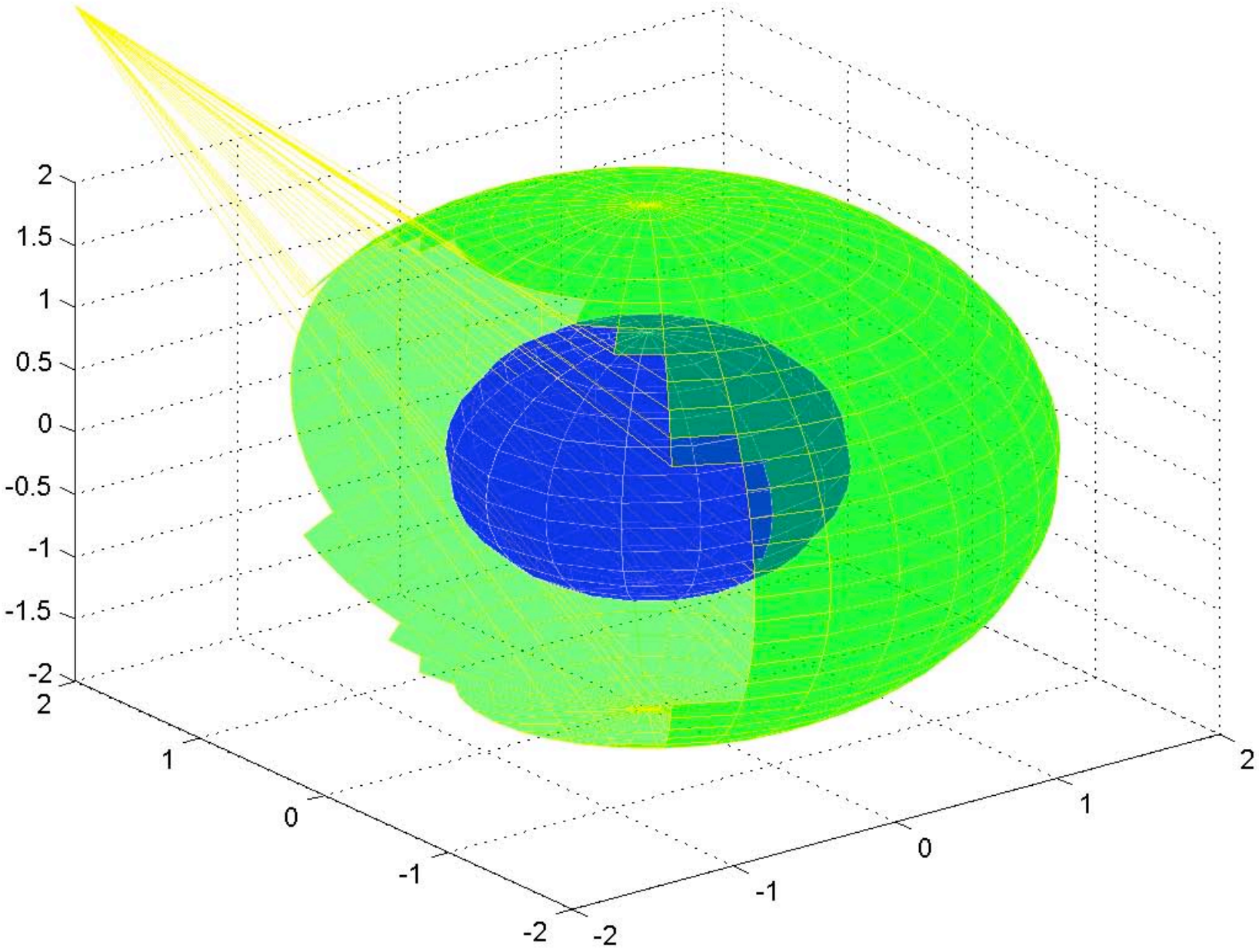

log( 1 / Voronoi Volume )
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-1
0
1
2

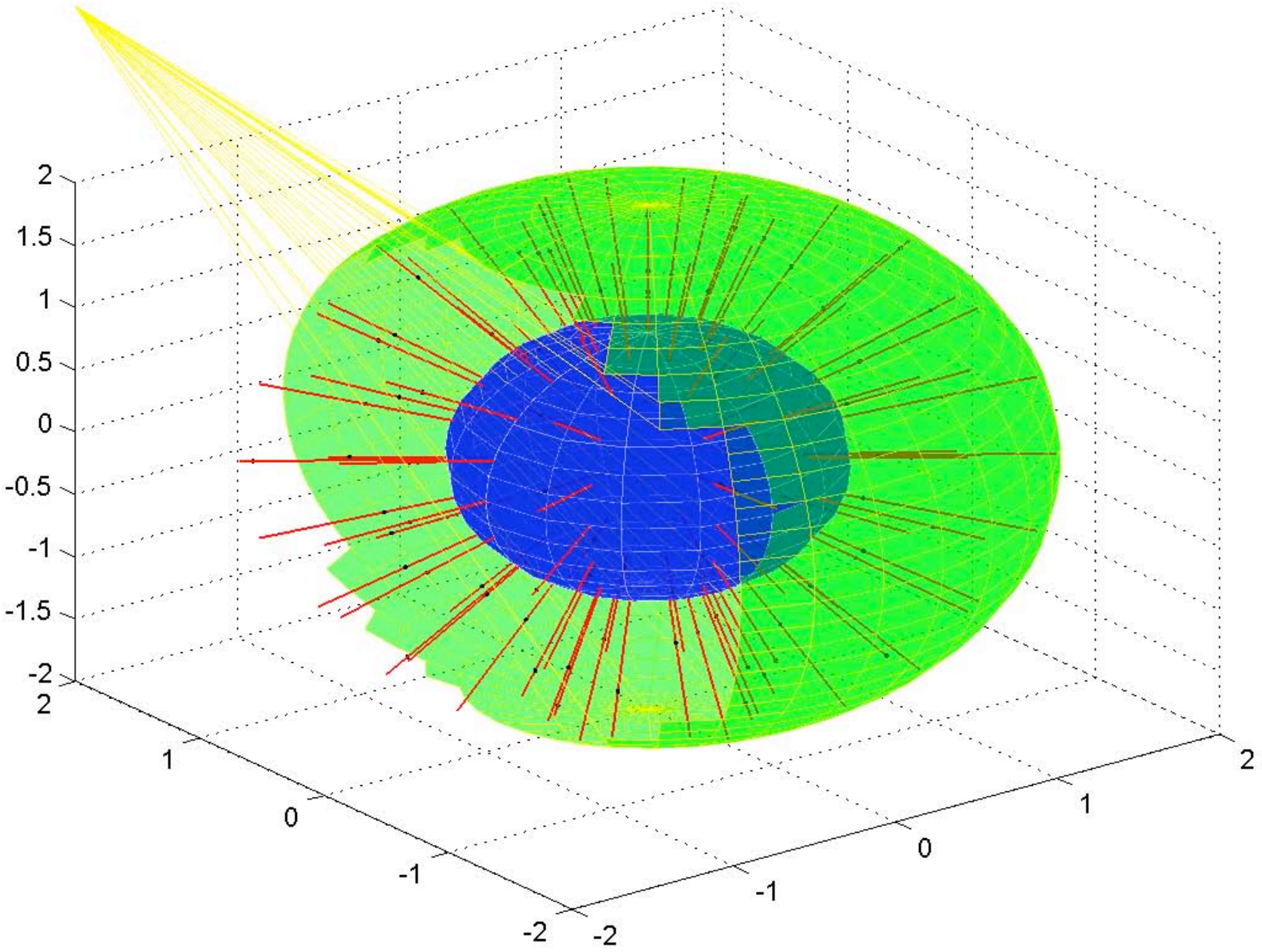
# Apportion Weights to Each Nearby Photon.

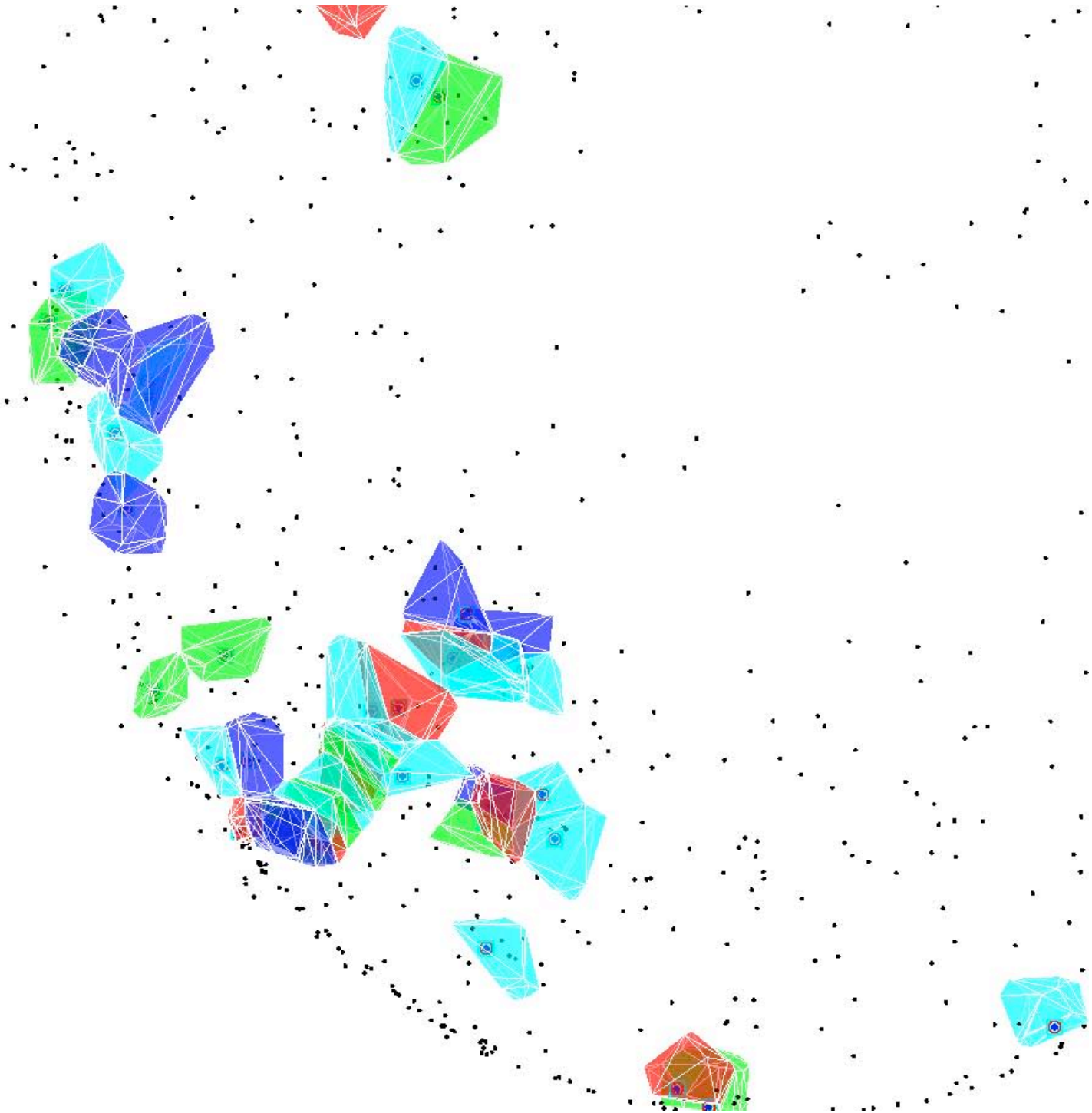


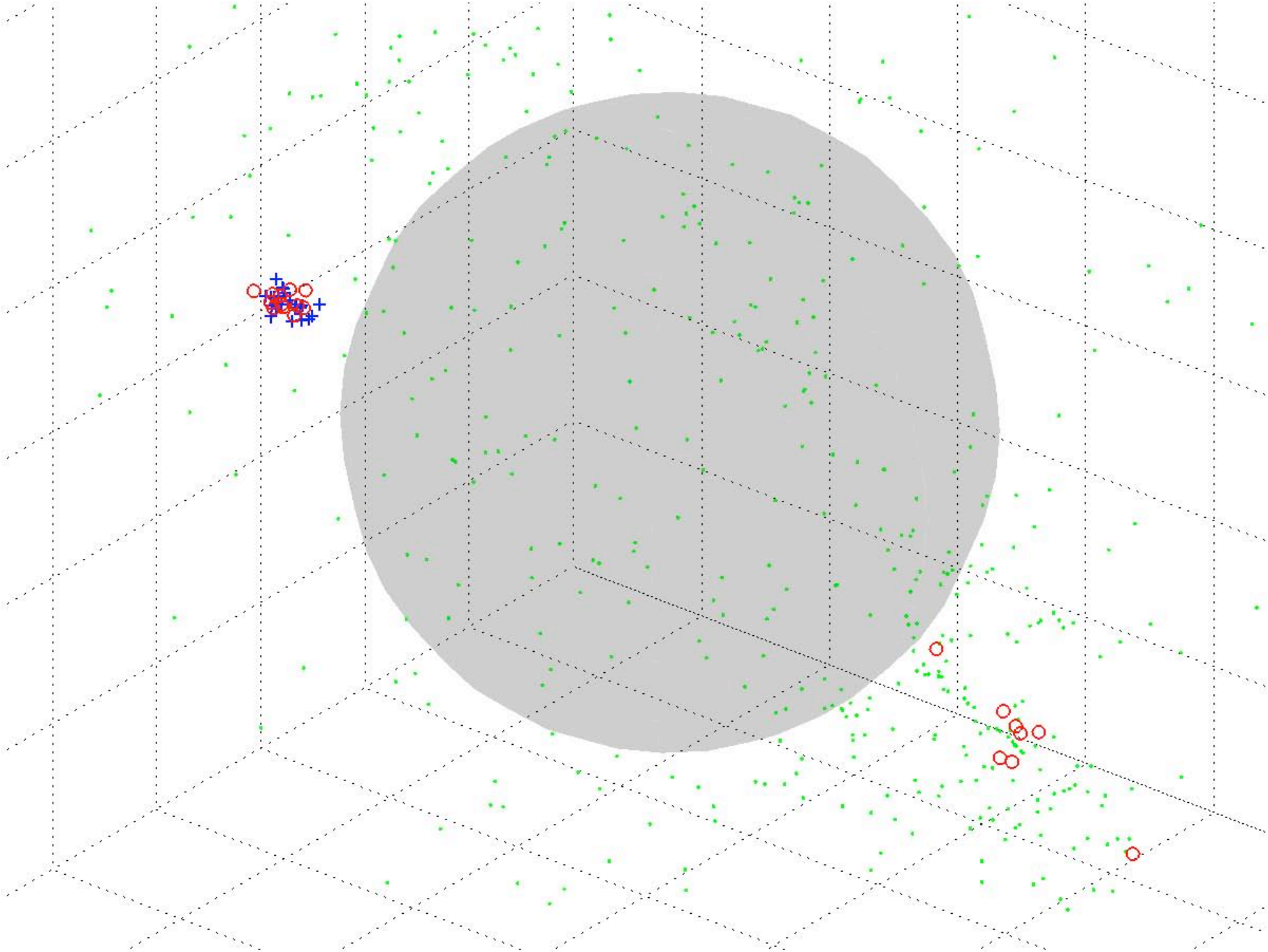

Differential: log( PSF Contribution / Voronoi Area )
4
2
0
-2
-4
-6
150
100
50
0
-50
-100
-150
Longitude
80
60
40
20
0
-20
-40
-60
-80
Latitude


2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
2
1
0
-1
-2
-2
-1
0
1
2


2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
2
1
0
-1
-2
-2
-1
0
1
2


2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
2
1
0
-1
-2
-2
-1
0
1
2





# Features of the Algorithm

- No Bins (space, time, energy)
- No Smoothing (space, time, energy)

(No loss of information due to these approximations. Result not dependent on bin sizes or locations.)

- Fast: O(N)
- Incremental: O( $\Delta$N ) – (work by Giuseppe Romeo)
- Suitable for quick look/automated science
- No Coordinate Singularities on the Sphere
- Flexible criterion for detection …

# Detection Criteria

Can evaluate the following at each photon:

- Local Density ( 1 / Voronoi volume)
- Clustering (connections to adjacent Voronoi cells)
- Difference in Spectrum (transient vs. background)
- Time difference (Voronoi volume vs. average of previous cell volumes nearby on the sky)
- Any other logically expressible criterion

… and incorporate them in the transient detection criterion.