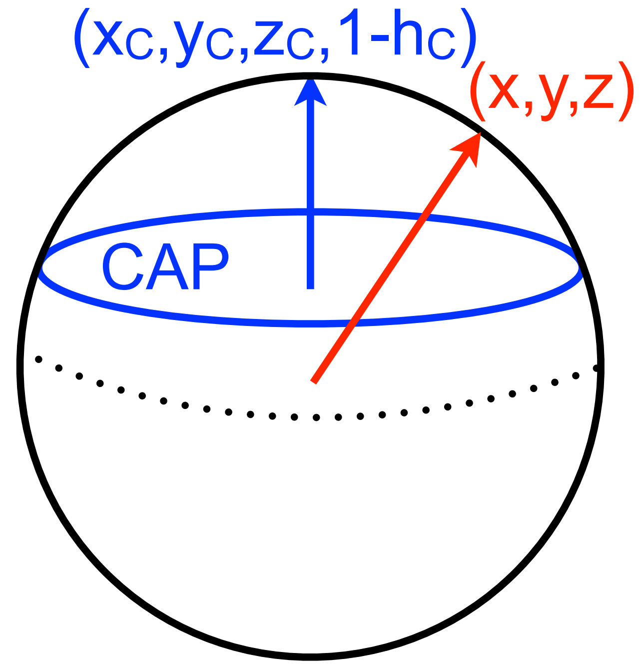
General Masking

Masking and Astronomical Surveys

- There are 3 main purposes to *Mangling* the sphere. The two purposes we will study are
  - to determine which objects in the sky lie within an arbitrary region defining a survey footprint
  - to populate that region with a catalog of random points to model the conditions of an *ideal* survey
- These two purposes are often referred to as "masking" or "creating a mask"
- The third purpose is to determine the *area* of the intersecting polygons used to model surveys
  - this requires a little extra math (applied to caps)
  - Areas are stored in a Mangle polygon as `str`

Spherical Cap Constraints



- The spherical cap formalism makes it easy to determine if points lie in intersections of polygons
- Consider whether a point (x,y,z) lies in the cap $(x_c,y_c,z_c,1\text{-}h_c)$
- Remember, $1\text{-}h_c=1\text{-}\cos\theta_c$ where θ_c is the "angular radius" on the sphere codified by the cap's size (called the cap *constraint*)
- Take the dot product between the cap and the point
  - $(x_c,y_c,z_c).(x,y,z) = |1||1|\cos\theta_{\textit{between cap and point vectors}}$
- Now if $\theta > \theta_c$ then the point lies outside of the cap and if $\theta < \theta_c$ then the point lies within the cap

Spherical Cap Constraints

- Algorithms to determine if points lie in spherical caps are very rapid, because they only require linear algebra
  - i.e. it is never necessary to use trigonometric functions (because if $\theta > \theta_c$ then $\cos\theta < \cos\theta_c$)
- In the *pymangle* version of *Mangle* that we installed last week, any mask (and by extension, any cap or polygon) can be tested against a set of (RA, dec) coordinates using *contains*, e.g.
  - *mask = pymangle.Mangle("file.ply")*
  - *ra = np.array([47.3, 152.7, 23.3, 280.4])*
  - *dec = np.array([-11.2, 12.2, 88.7, -39.2])*
  - *good = mask.contains(ra, dec)*

Random Catalogs

- In the *Areas on the Sphere and HEALPix* notes, I provided equations for populating the sphere in equal-area angular projection with random points
- To construct such a random catalog in a collection of polygons, we could populate the entire sphere in equal-area projection and then use *mask.contains* to find just the points that lie in the mask
- *pymangle* implements a similar method for making random catalogs in masks called *genrand*
- We already used *genrand* in the previous lecture, e.g.
  - *mask = pymangle.Mangle("file.ply")*
  - *ra_rand, dec_rand = mask.genrand(10000)*

Random Catalogs and weights

- One part of a *Mangle* polygon I have yet to discuss in detail is the `weight`
- The reason for different `weights` is that when *genrand* creates a random catalog it will create proportionately more random points in polygons with more `weight`
- This has real applications to astronomy. Consider taking spectroscopy of a plate of targets in the sky, for which good spectra are obtained for 80%
- If that plate is modeled as a polygon then `weight=0.8`
- The `weight` of a second plate might also be `0.8` but the weight of the *intersection* of the two plates should be higher, *as more objects can be observed in the overlap*

Python tasks

1. Create a polygon in a *Mangle* file consisting of 4 caps that define a "lat-lon rectangular" field bounded in RA by 5^h and 6^h and in declination by 30^o and 40^o
   - Use the *ra_cap* and *dec_cap* functions you wrote as part of the *Spherical Caps* lecture
   - In the *Areas on the Sphere and HEALPix* notes, I showed that the area of a "lat-lon rectangle" in steradians is $(\alpha_2^{radians} - \alpha_1^{radians})(\sin\delta_2 - \sin\delta_1)$
   - *Calculate* the correct `str` area for your polygon, add it to the file, and give the polygon a `weight` of 0.9
2. Add a second polygon to your file for a field bounded in RA by 10^h and 12^h and in declination by 60^o and 70^o
   - add `str` for this polygon, and give it a `weight` of 0.2

Python tasks

3. Create a random catalog of 1 million objects distributed over the entire sphere
   - See, e.g., the *Areas on the Sphere and HEALPix* notes
4. Use *mask.contains* to determine which points in your random catalog lie within the "lat-lon rectangular" polygons in your file
   - plot the entire random catalog, and over-plot just the points that lie within the polygons in a different color
5. Use *mask.genrand* to generate 10,000 random points within your polygons
   - Is the density of random points that *genrand* creates the same in each of your polygons? Why or why not?