Introduction to project 4: fiber tracking

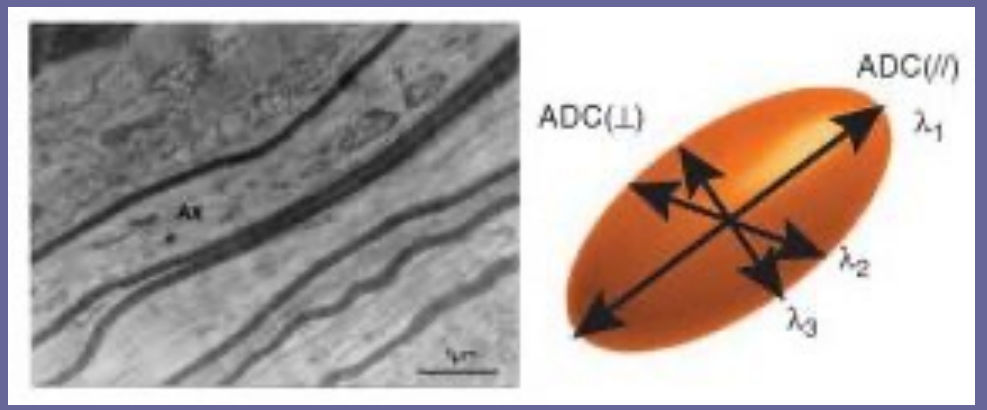
Quantitative and Functional Imaging

BME 4420/7450

Fall 2022

Water diffusion reflects tissue microstructure

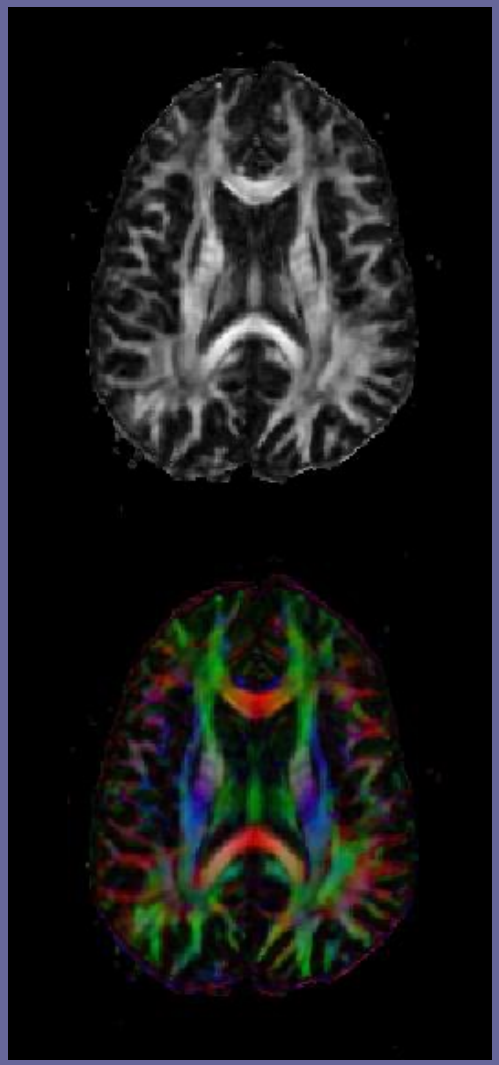
- Diffusion of water in brain tissue
  - Constrained by cell membranes
  - Preferred direction of membranes -> preferred direction of water diffusion
- Largest displacements
  - Parallel to axons
- Variation of displacements over orientations reflects
  - Membrane permeability
  - Membrane density
  - Fiber coherence



Jones (2011)

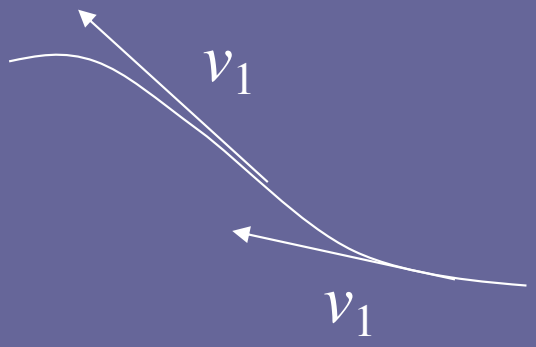
Anisotropy reveals fiber bundle orientation

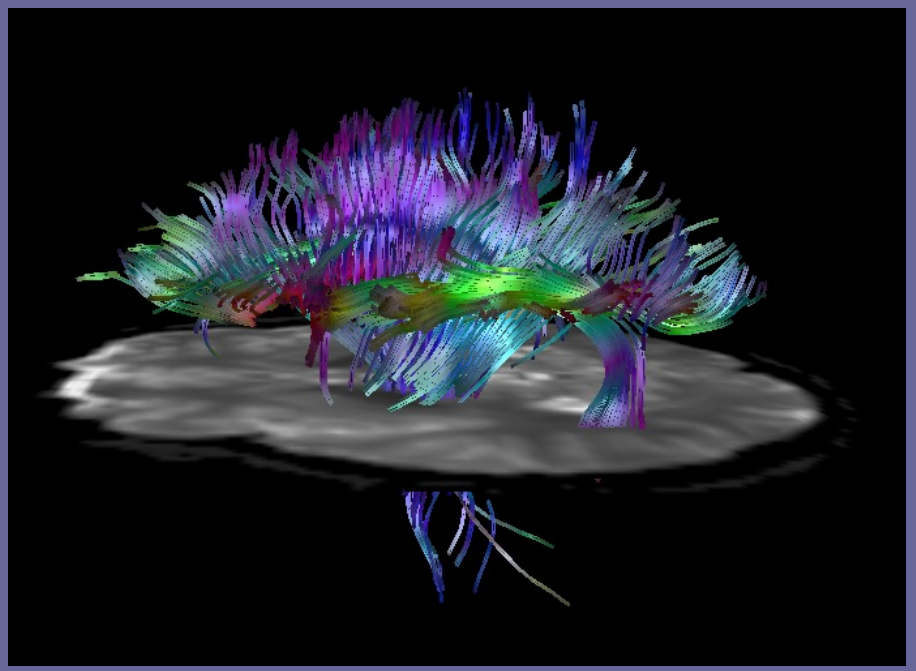
- Anisotropy maps
  - Bright in coherent white matter
  - Darker
    - Where fibers diverge
    - In gray matter
- Orientation information
  - Color code FA by direction
    - Red = Right/Left
    - Green = Anterior/Posterior
    - Blue = Superior/Inferior
- Reveals structure within white matter



Fiber tracking

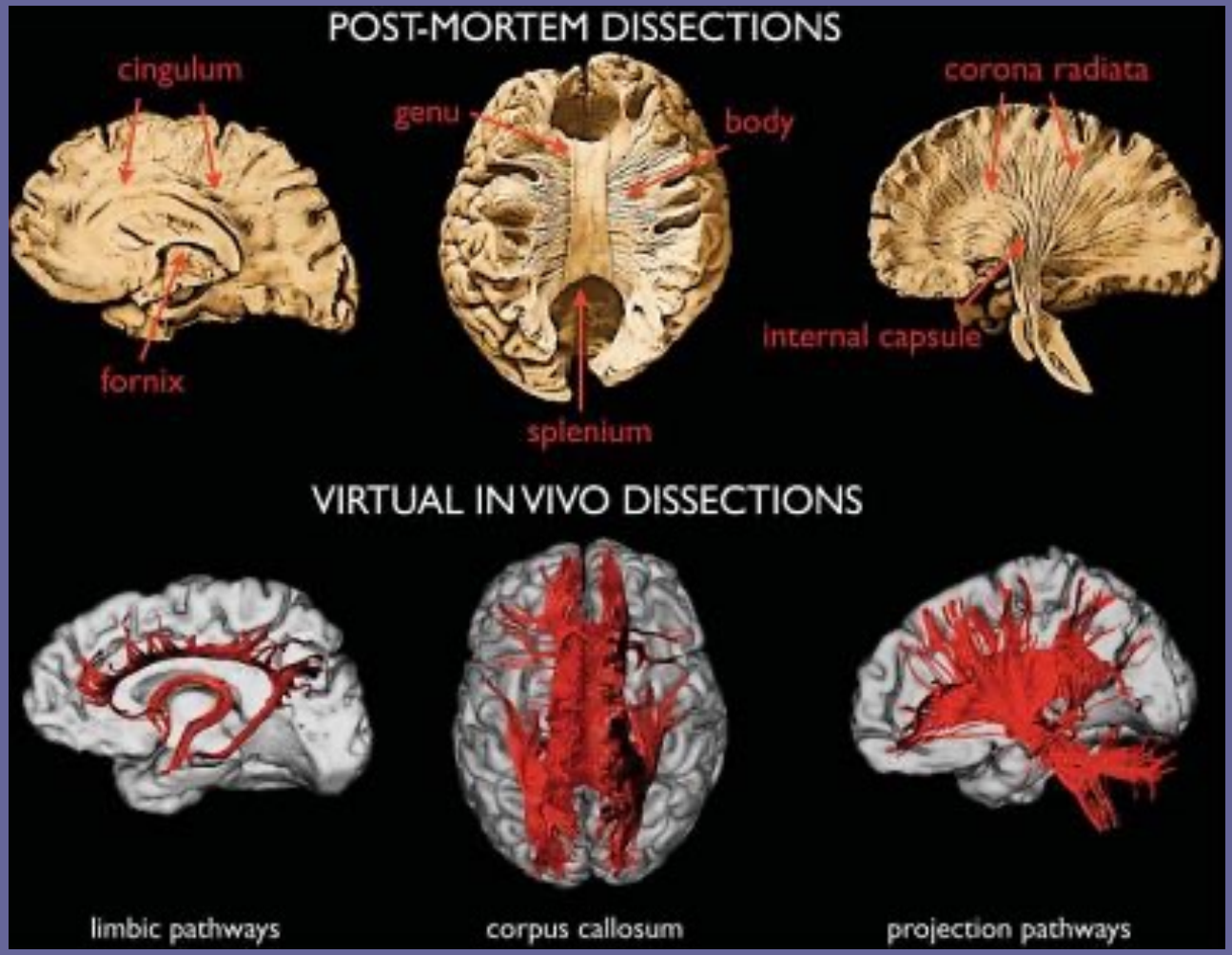
- Fiber paths calculated from fast diffusion direction



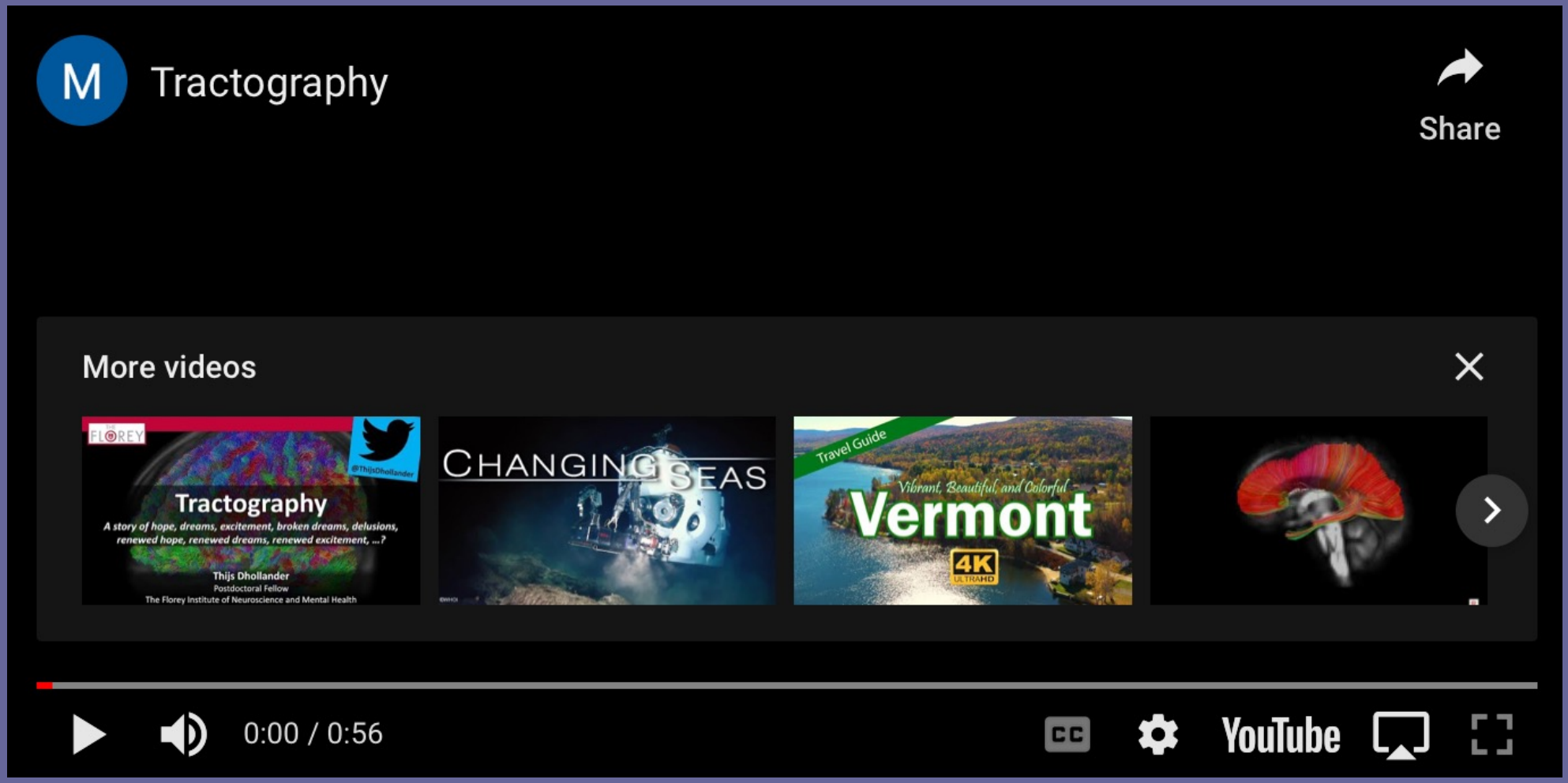


- Integrate starting from user-defined seed points

Tractography for white matter segmentation



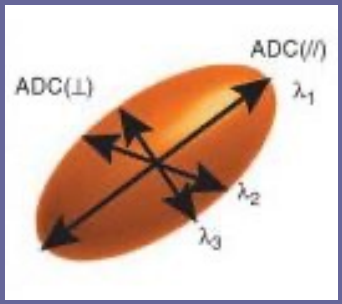
Jones (2011)



https://youtu.be/wy8KEUmyasA

Project data

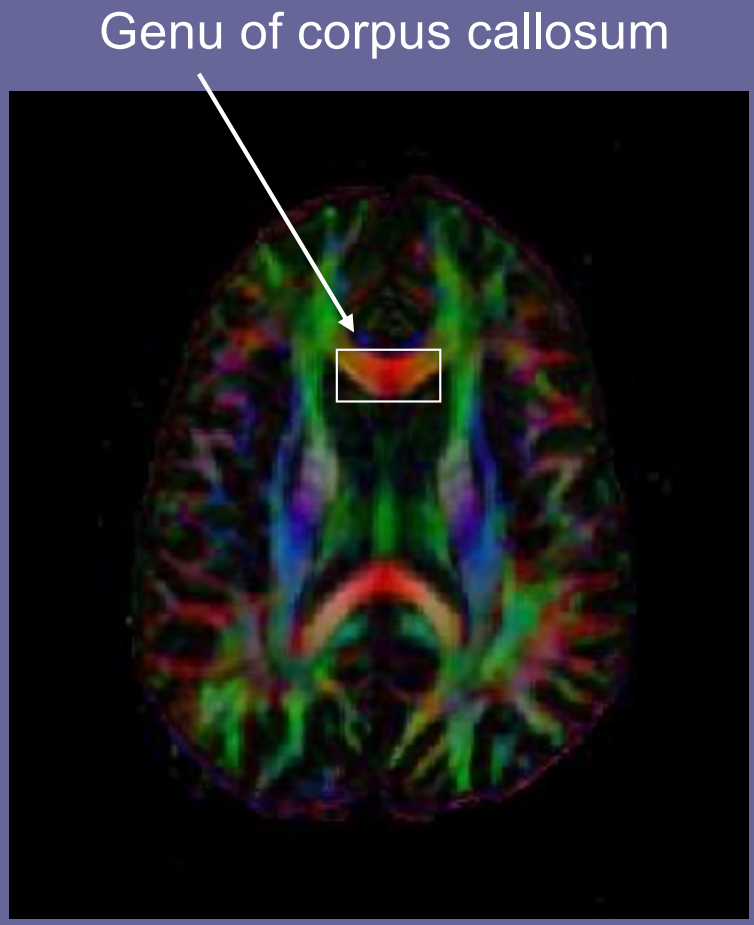
- Anatomical image of brain slice (anat_m)
  - T2 weighted image (256x256 array)
- Fast diffusion direction in each voxel (fastDiffVector_3d)
  - Elements: X, Y, and Z components of unit vectors (256x256x3 array)
  - Indices are fastDiffVector_3d(row,col,component)
- Diffusion coefficients along the principal directions of brain tissue (eigValues_3d)
  - Elements: λ_1, λ_2, and λ_3 (256x256x3 array)



Jones (2011)

Goals of project

- Map fractional anisotropy in the image plane
- Create a fiber tracking algorithm
- Use your algorithm to track fibers through the corpus callosum
- Quantify properties of the fiber pathway



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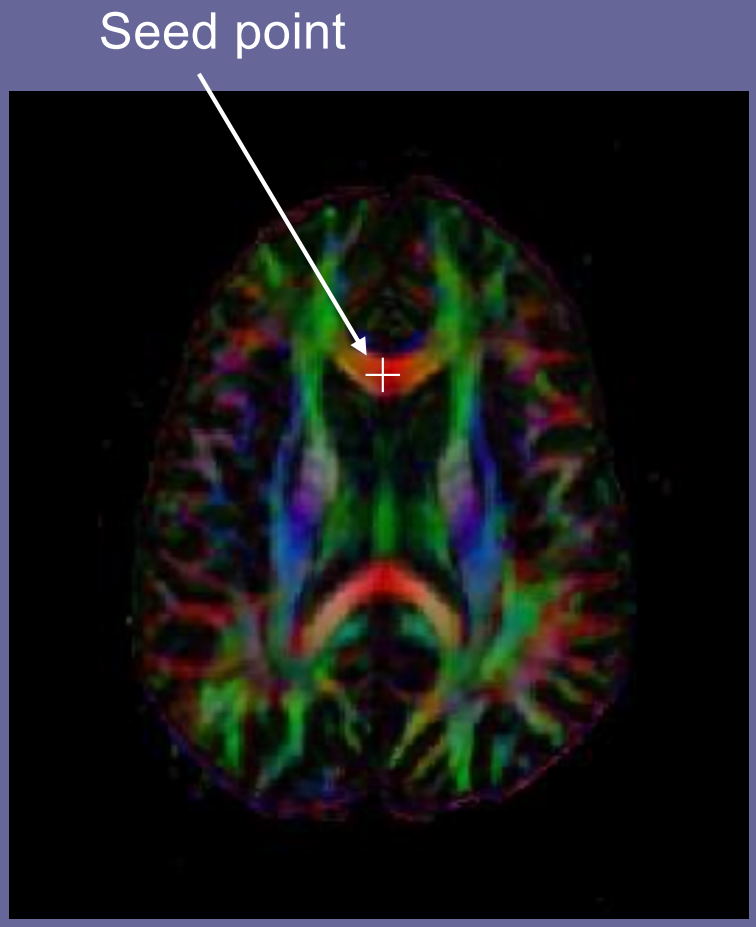

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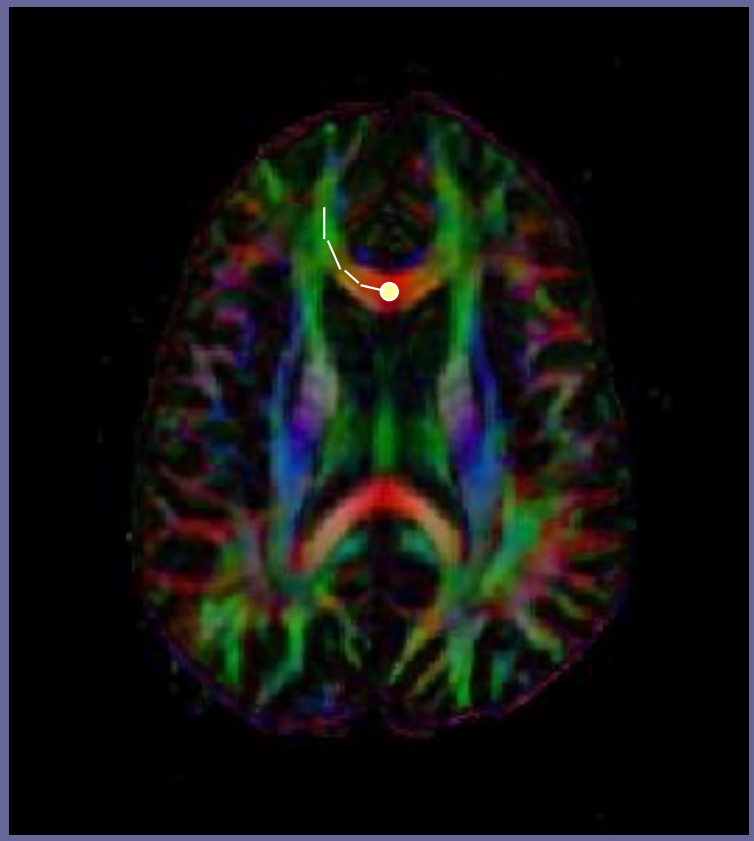

Problem #1

- We want to track fibers in a single plane, but the fibers may leave the plane
- One solution:

```
% Break out of the while loop if the in-plane component of the
% vector is too small:
if (sum(fast_v.^2) < 0.5)
    disp('In-plane component of fast_v is too small')
    break
end
```

Problem #2

- The fast diffusion direction (vector) gives the orientation of fibers, but has arbitrary sign
  - What if the vector is opposite to the stepping direction?
- One solution:

```
% If this is not the first step away from the seed point, calculate
% cosAngle, the cosine of the angle between the previous step and
% fast_v. If cosAngle is negative, reverse the direction of fast_v
```

Problem #3

- When diffusion anisotropy is low, direction information is unreliable (random)
  - How do we know when to stop tracking?
- One solution:

```
% If this is not the first step away from the seed point, calculate
% cosAngle, the cosine of the angle between the previous step and
% fast_v. Stop tracking if abs(cosAngle) is too small.
```