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Advances in Angle Sensitive MRI:

Towards *in-vivo* analysis of collagen fiber tracts in the Anterior Cruciate Ligament

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Declaration of Financial Interests or Relationships

Speaker Name: Karyn E Chappell

I have no financial interests or relationships to disclose with regard to the subject matter of this presentation.

Rationale

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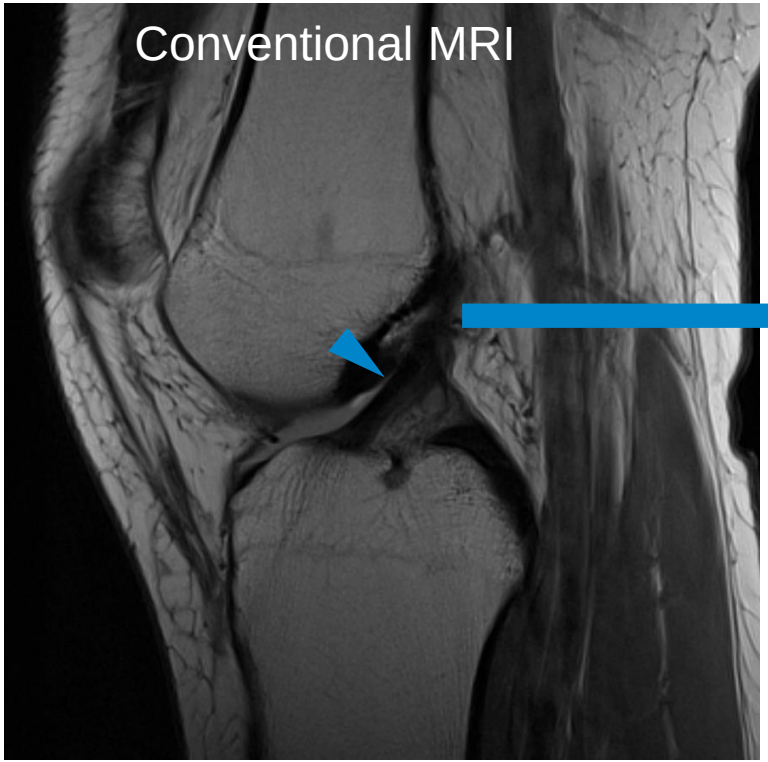
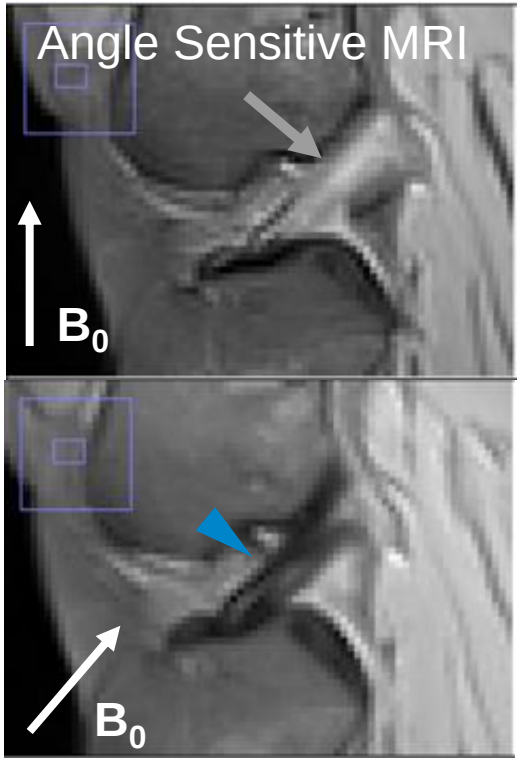


Exploit the Magic Angle Phenomenon

Magic Angle θ = 54.7˚

$$I = \exp(-(3cos^2\theta - 1)^2)$$



Background

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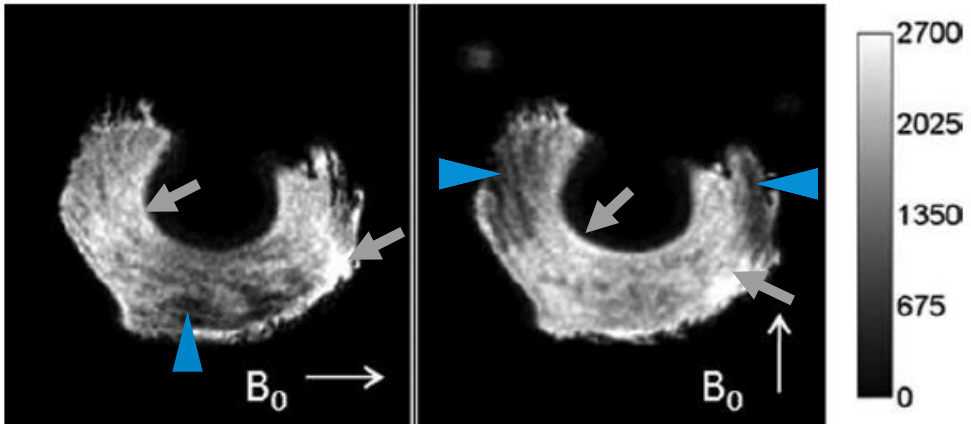
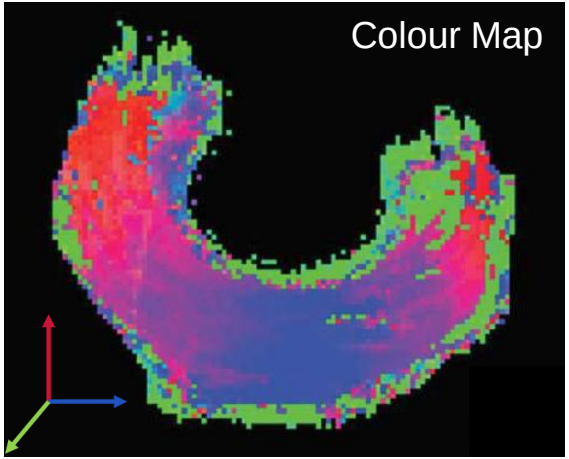
Dipolar Anisotropy Fibre Imaging (DAFI) from Szeveneyi & Bydder (MRM 2011)





Bright signal intensity at magic angle

Dark signal intensity when parallel to B_0

15 directions = 3 hrs 30 mins

3 planes x, y, z in 30 degree increments

Background

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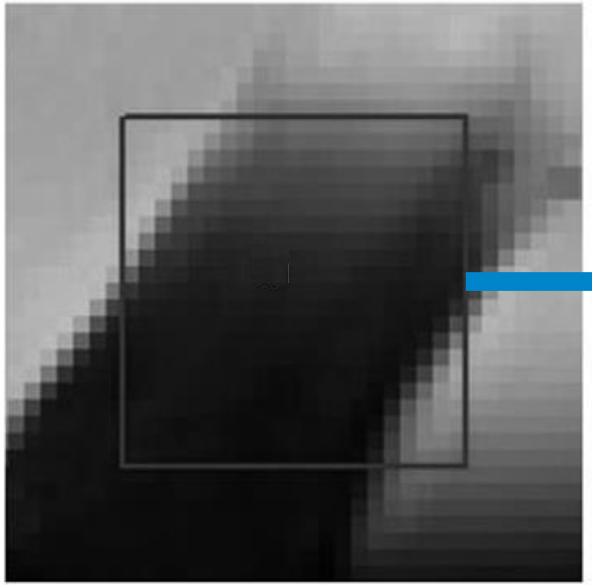
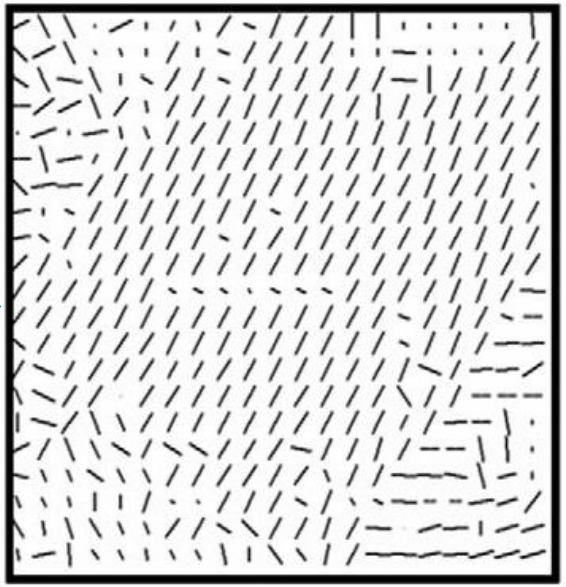
Angle Sensitive MRI described by Seidel *et al*. (MRM 2013)



35 directions = 2 hrs 20 mins

ONLY 2 planes (x,z) in 10 degree increments



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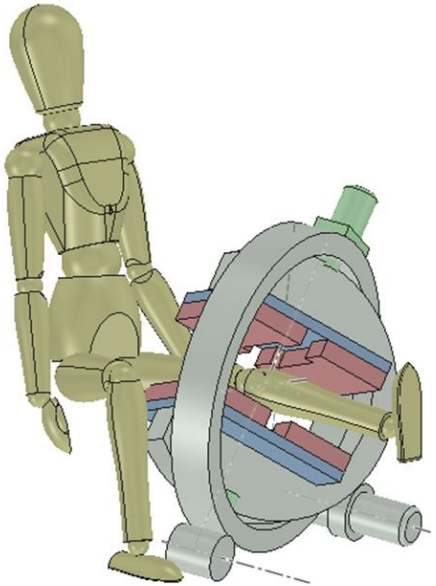
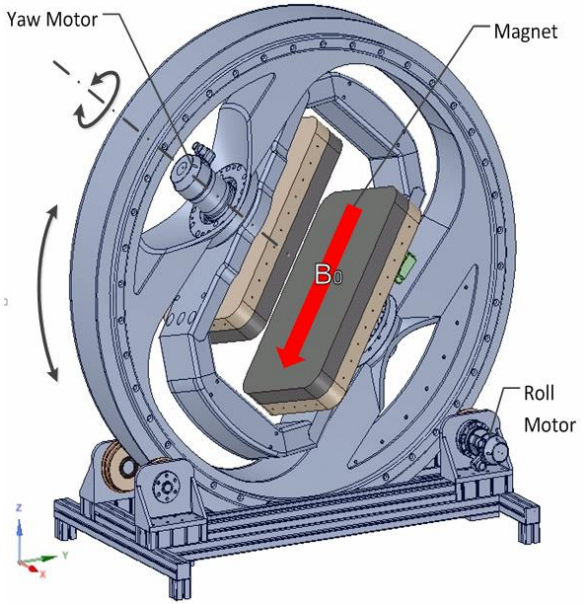
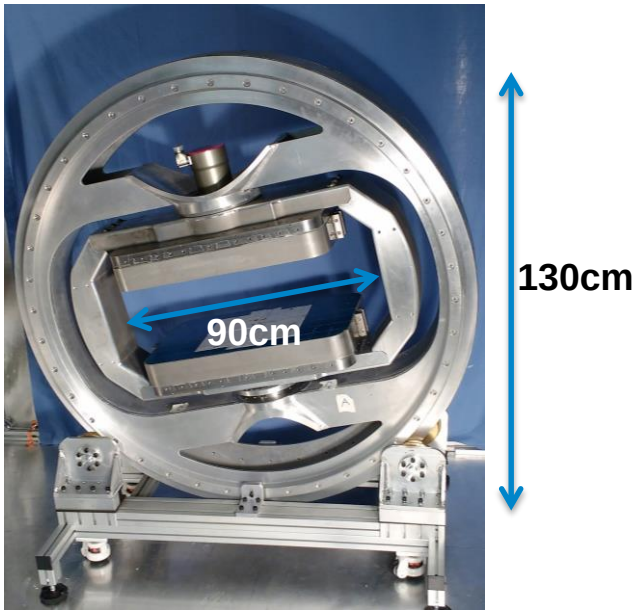
Magic Angle Scanner

A novel open MRI system from McGinley *et al.* (JMR 2016)







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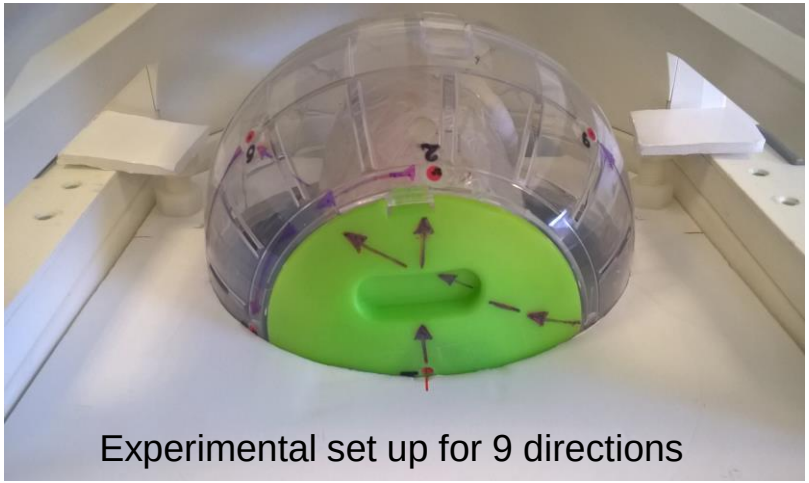
Method

- Siemens Verio 3T
- 12 channel head coil
- 3D 1x1x1mm isotropic sequence optimized for angle sensitive contrast
- Sphere containing caprine knee

- Sphere was rotated and scanned in;
  - 15 directions (DAFI)
  - 9 directions
  - 7 directions
  - 5 directions



Experimental set up for 9 directions

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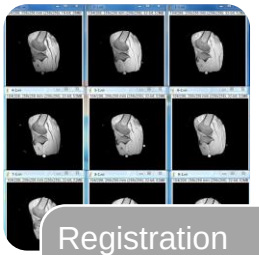
Post Processing



Registration

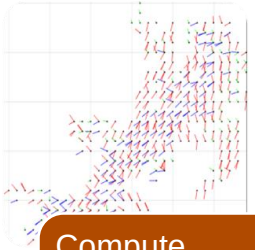
- slices were aligned to match the initial position

Angle Sensitive volume

- Based on standard deviation of intensity across *n* volumes

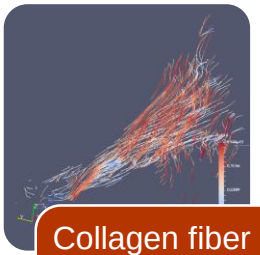
Segmentation

- identifies voxels which show angle sensitive contrast - the magic angle effect



Compute collagen orientation

- Improved Szeverenyi and Bydder algorithm



Collagen fiber visualisation

- ParaView - 3D visualization of fiber tracts

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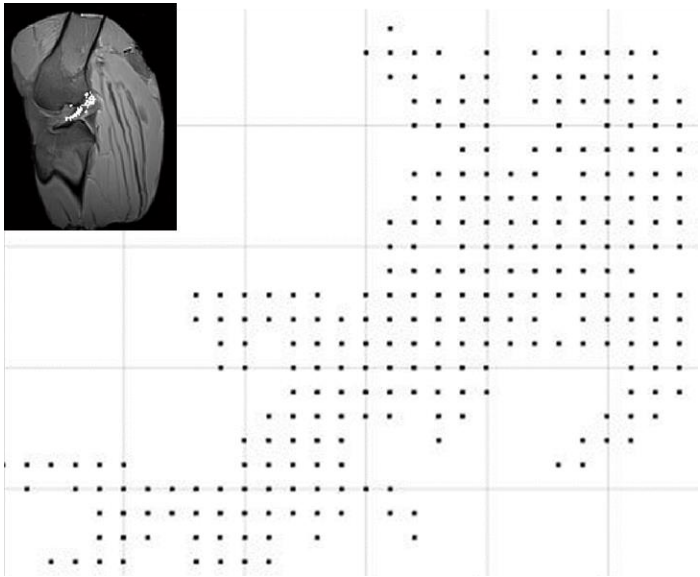
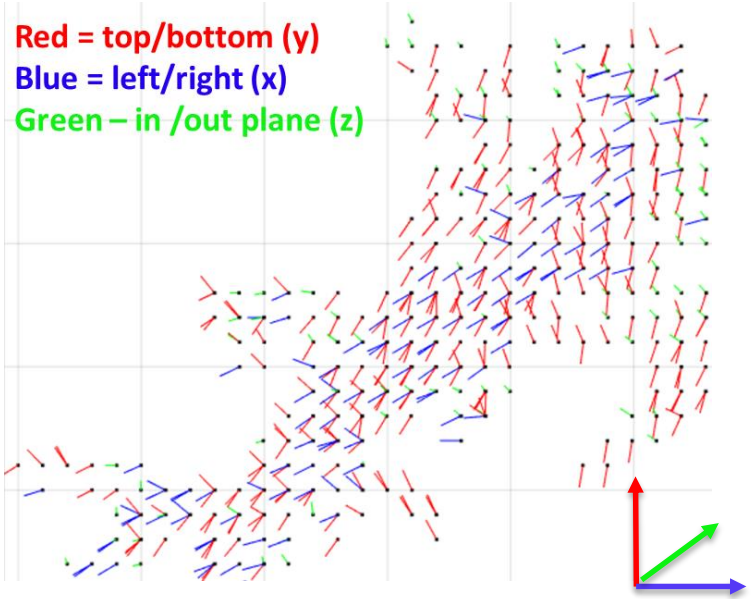
ACL Results

Collagen containing voxels



Voxels with orientation vector of net collagen direction



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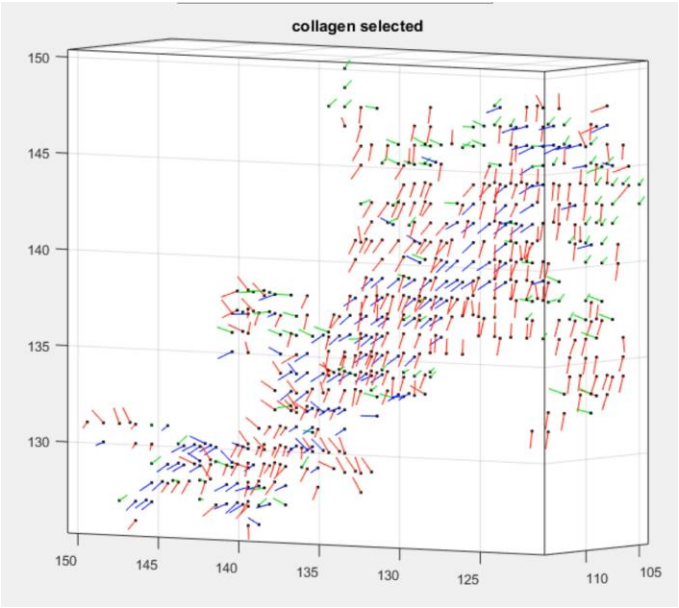
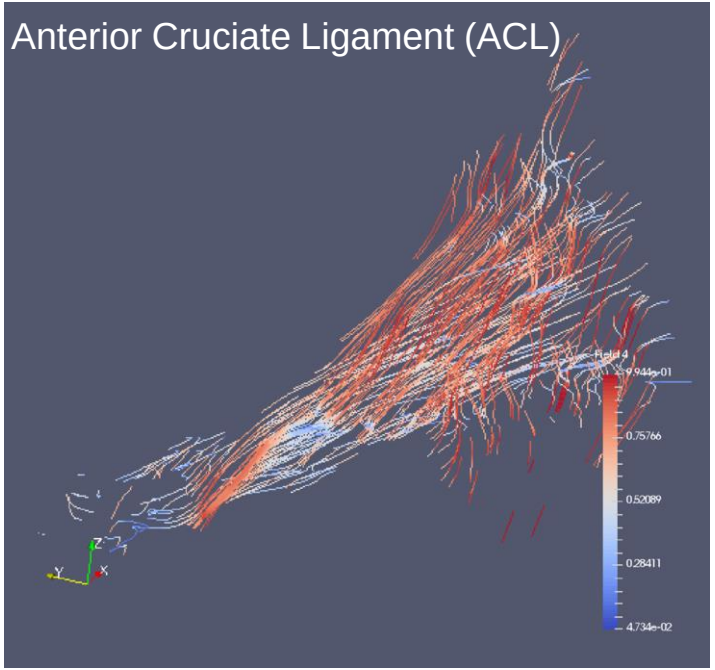
ACL Results





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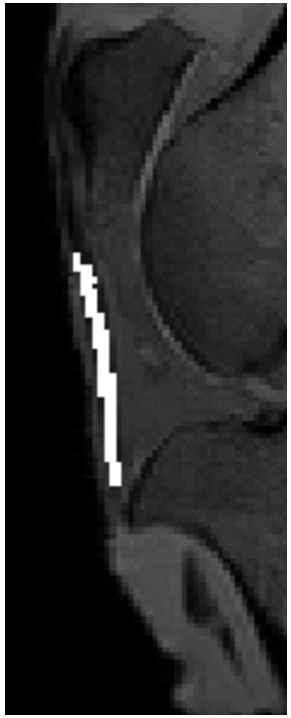
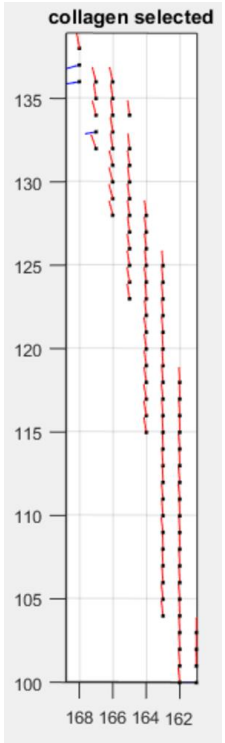
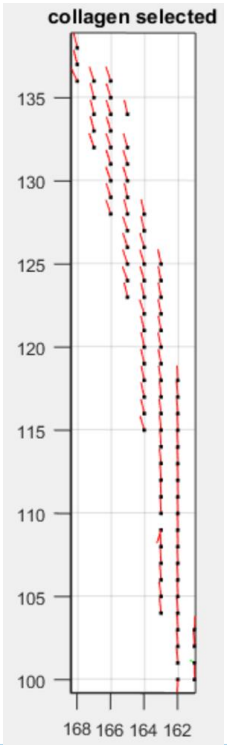
Optimal number of directions



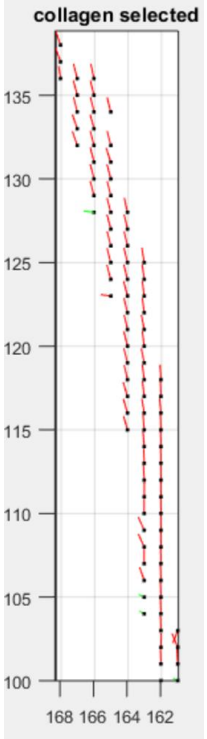
15 directions



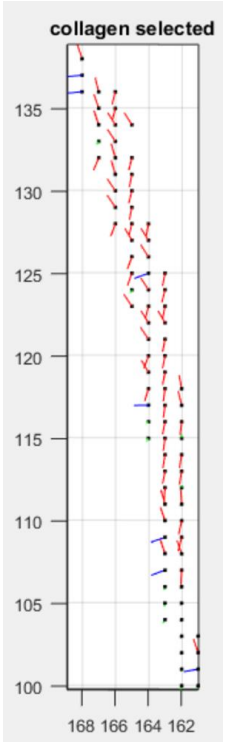
9 directions



7 directions



5 directions



- 15 directions = 3 hrs 30 mins
- 9 directions = 1 hrs 15 mins
- 7 directions = 59 mins
- 5 directions = 43 mins

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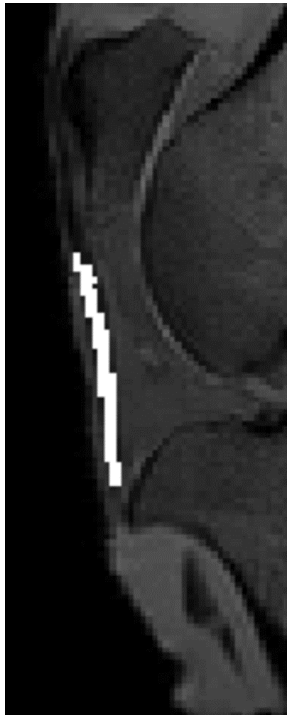
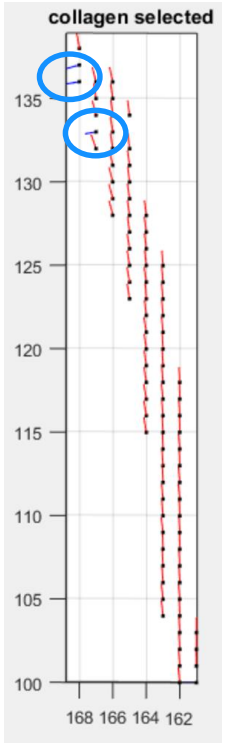
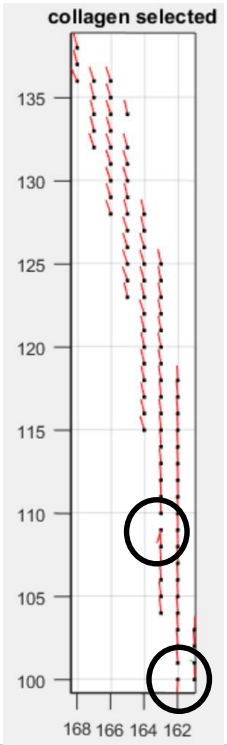
Optimal number of directions



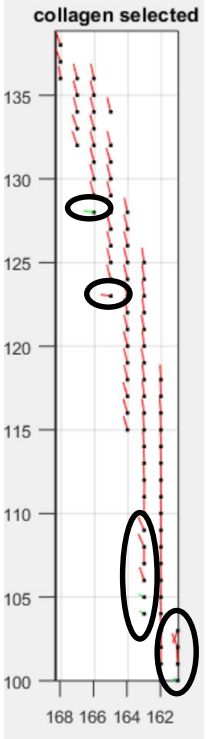
15 directions



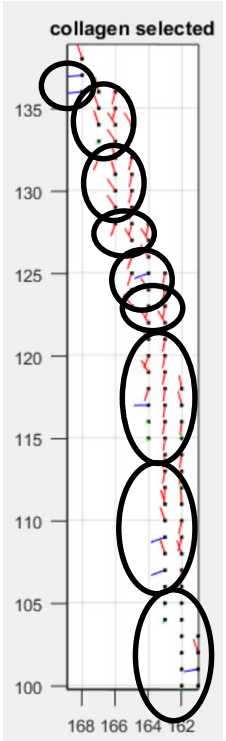
9 directions



7 directions



5 directions



- 15 directions was taken as the standard
- 9 directions compares favourably with 15.
- 5 directions is insufficient to compute net collagen direction

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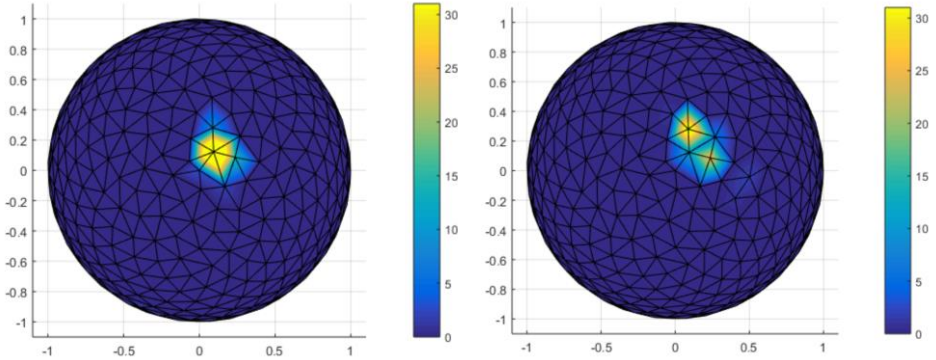
Optimal number of directions

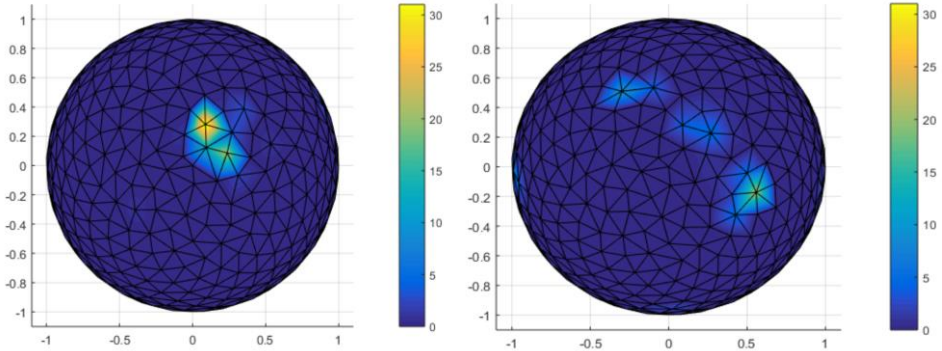
Anisotropy Index (AI)

15 directions : AI = 0.9506

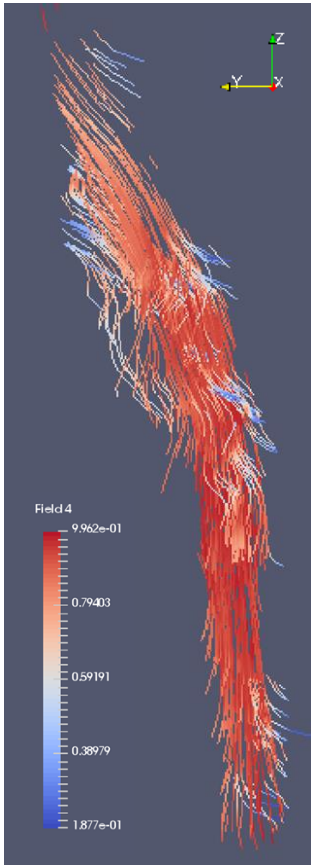


9 directions : AI = 0.9529

7 directions : AI = 0.8941



5 directions : AI = 0.3415



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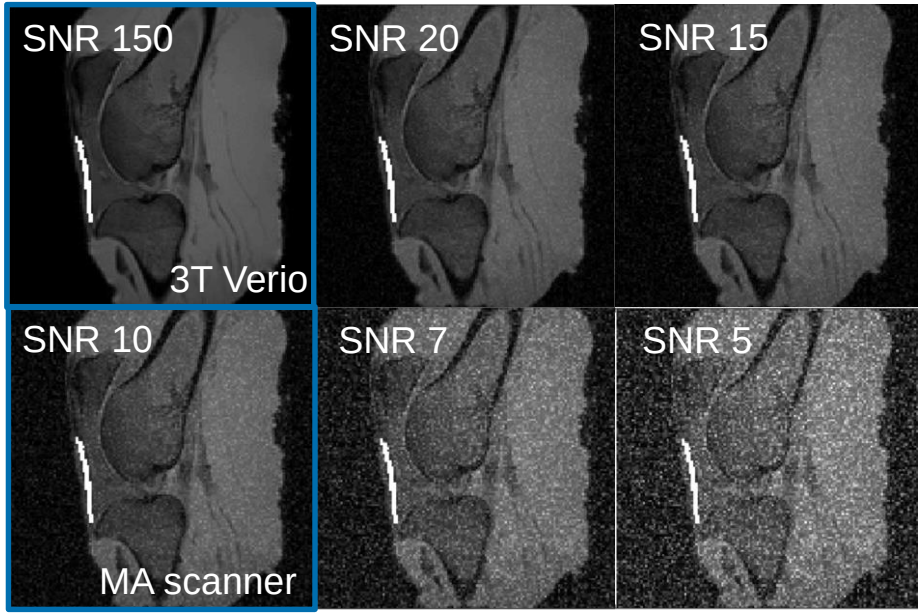
Discussion

- Number of directions required depends on image noise
- The greater the noise the more directions are needed.
- For *in vivo* angle sensitive MRI:
  - Moving B_0 = MA Scanner
  - 9 directions = 1 hr 15 mins
- Up to 3 times faster than previous methods.



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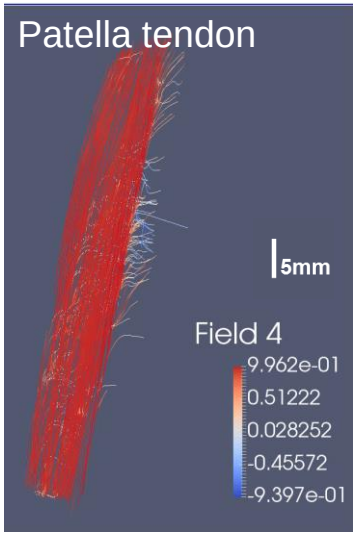
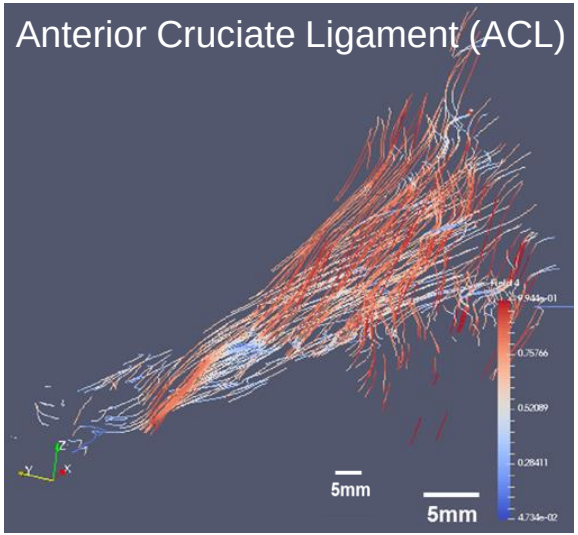
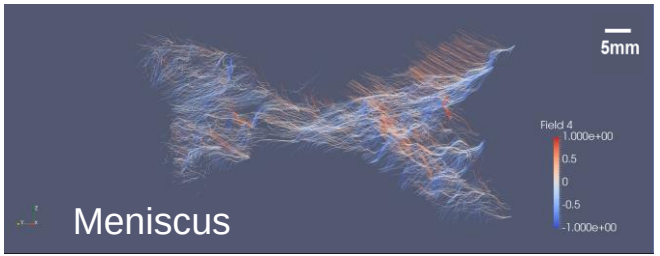
Conclusion

- Optimum number of directions is less than previously published.
- Results used in prototype Magic Angle scanner development.

- Angle sensitive MRI can enhance the information hidden in highly orientated collagen structures, improving clinical decisions.







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