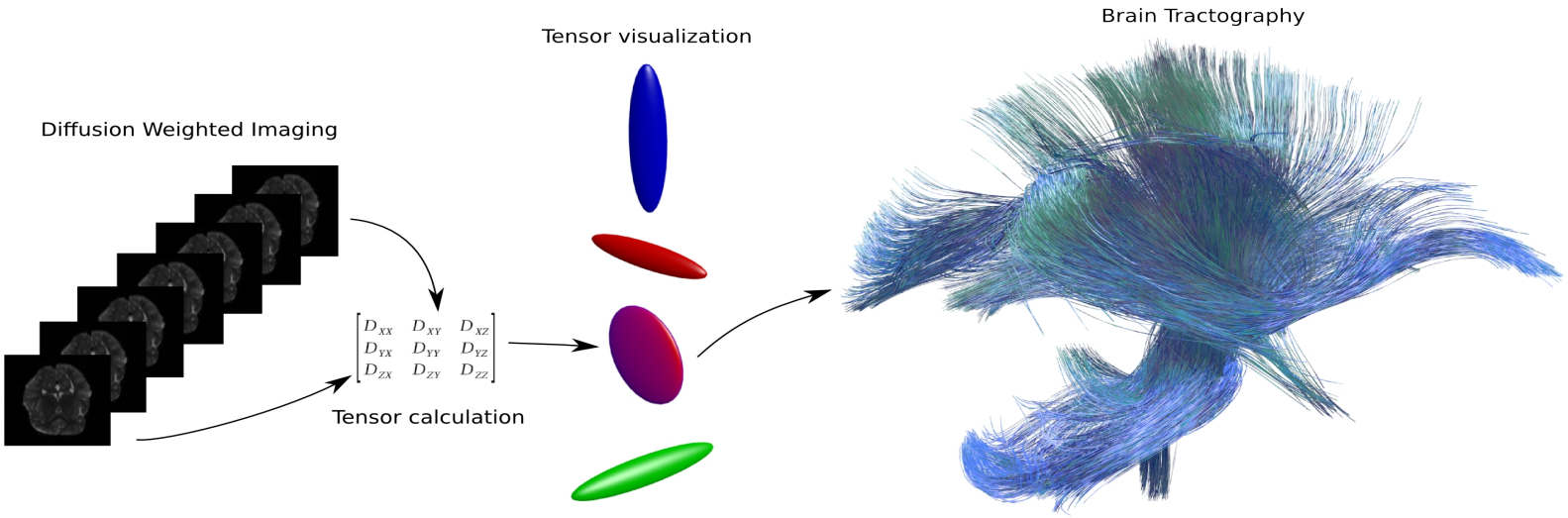


Diffusion Tensor Imaging quality control : artifacts assessment and correction

A. Coste, S. Gouttard, C. Vachet, G. Gerig

SCI INSTITUTE

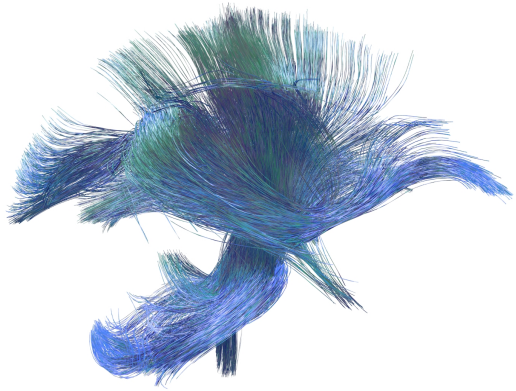
Medical Imaging Seminar

Overview

- Introduction
- DWI – DTI
- Artifact Assessment
- Artifact Consequences
- Artifact Detection
- Possible Correction
- Conclusion

Introduction

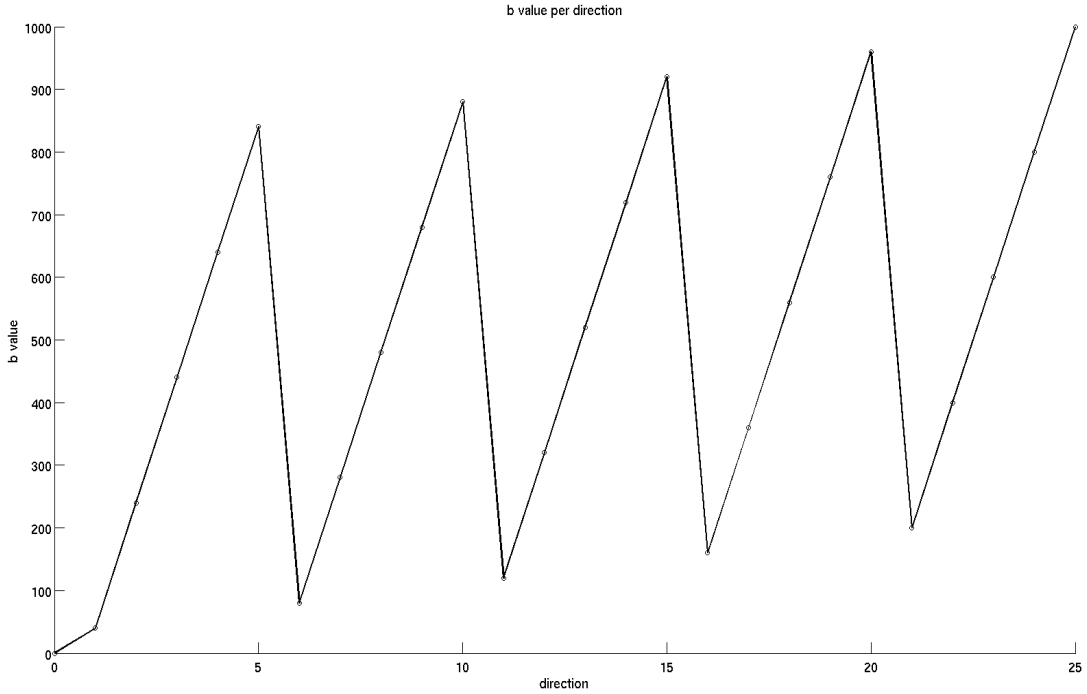
- DTI is a powerful technique giving insights into white matter organization
- Allows Tractography
- Increased Artifacts
- Reduced Signal to Noise Ratio
- Need of Quality Control
- Need of new processing methods to process DTI due to new kind of artifacts



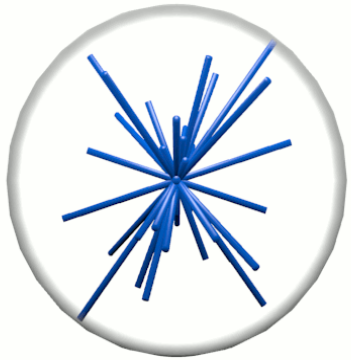
Diffusion Weighted Imaging

- Acquisition of multiple set of MRI with several values of the exciting magnetic field and with different orientation.
- In our protocol we use 25 different directions

b value



direction



Diffusion Tensor Imaging

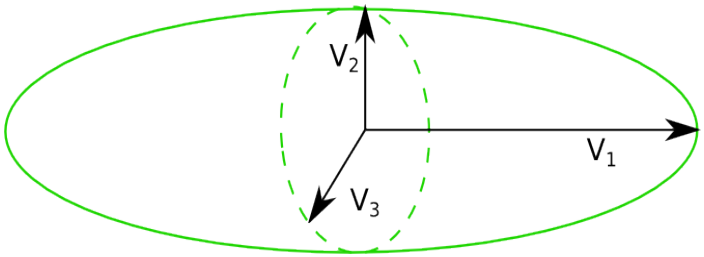
- DTI is computed with an overdetermined system based on all images of the DWI set.
- Each voxel contains a second order diffusion Tensor :

$$D = \begin{bmatrix} D_{XX} & D_{XY} & D_{XZ} \\ D_{YX} & D_{YY} & D_{YZ} \\ D_{ZX} & D_{ZY} & D_{ZZ} \end{bmatrix}$$

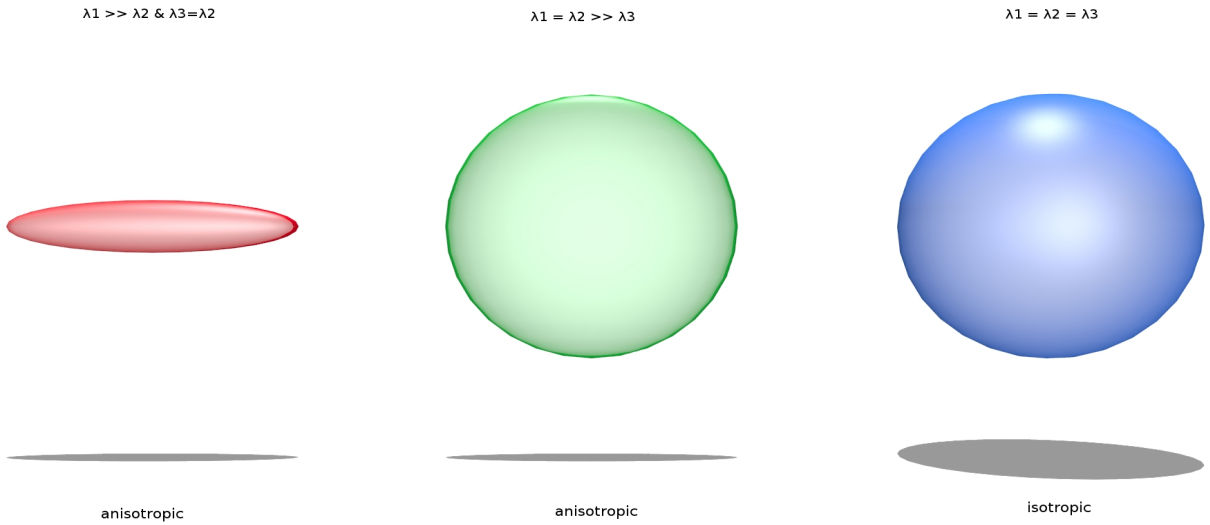
- D is symmetric and positive definite
- To visualize the tensor we use Eigen decomposition to get the local diffusion characteristics

DTI Visualization

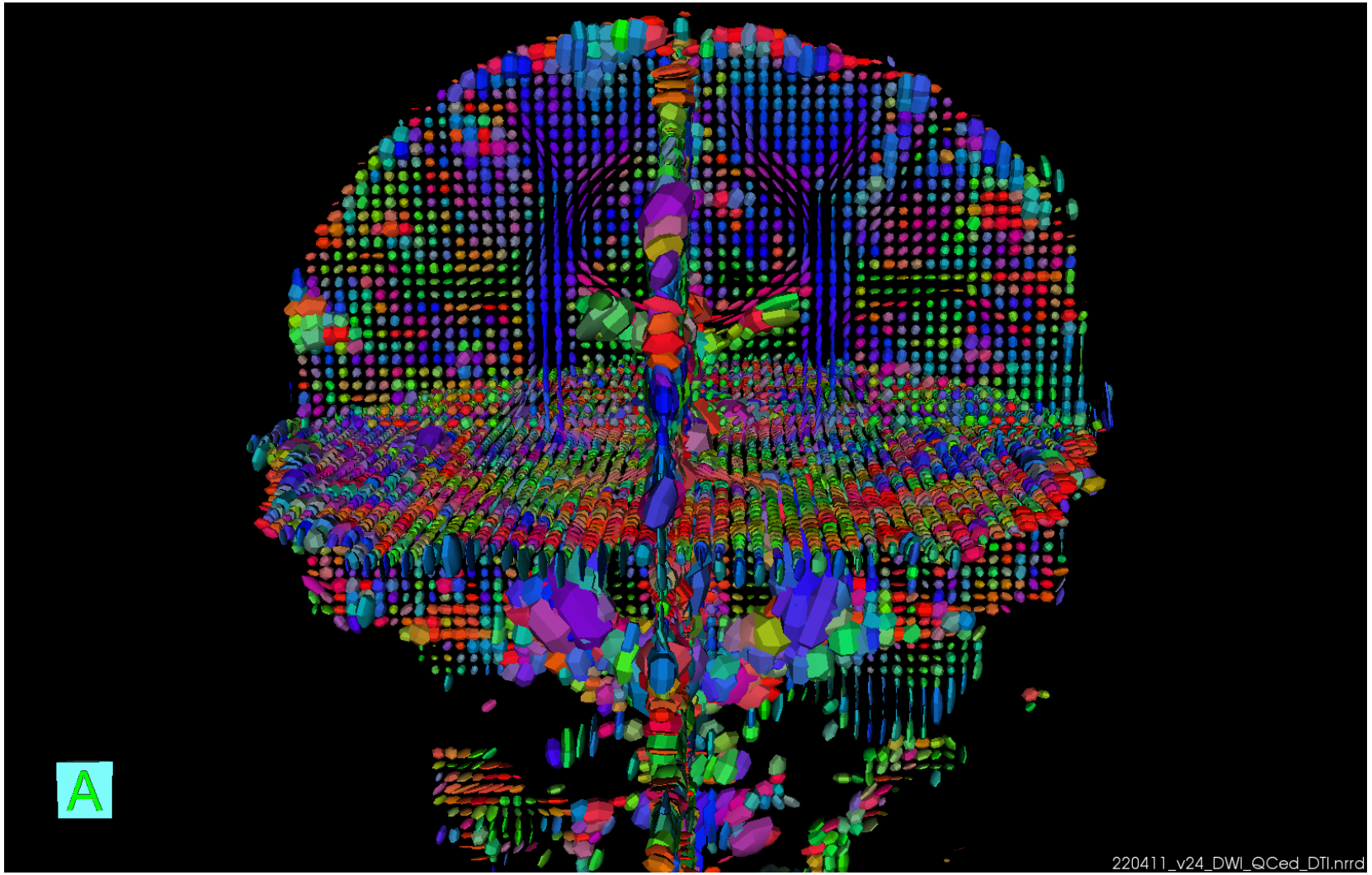
- Ellipsoid parametrization with eigen vectors and eigenvalues



- Interpretation of diffusion properties



DTI Visualization

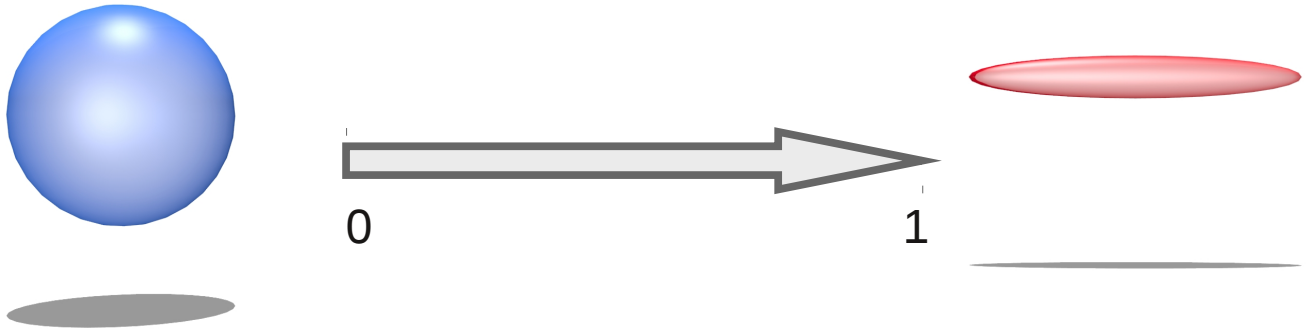


Fractional Anisotropy

$$D = \begin{bmatrix} D_{XX} & D_{XY} & D_{XZ} \\ D_{YX} & D_{YY} & D_{YZ} \\ D_{ZX} & D_{ZY} & D_{ZZ} \end{bmatrix}$$

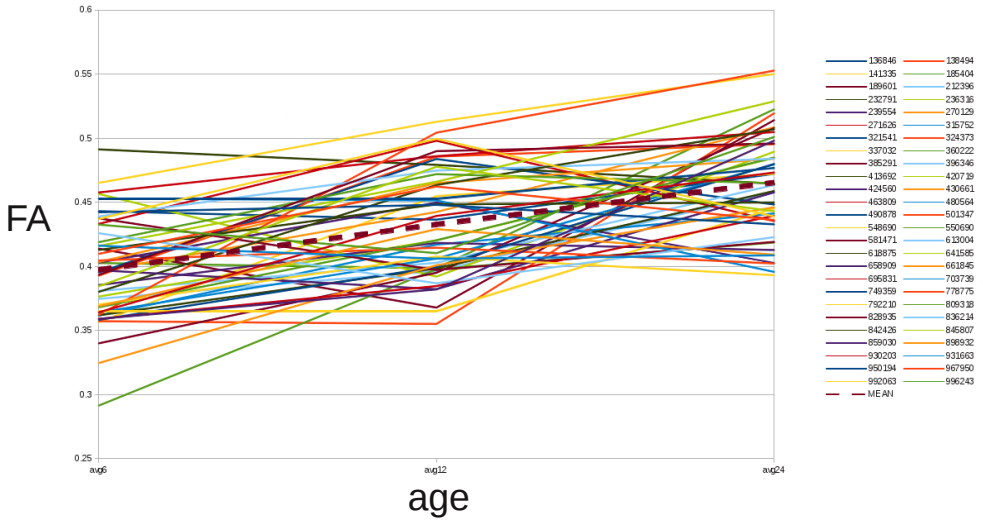
- Fractional Anisotropy (FA)

$$FA = \sqrt{\frac{1}{2}} \frac{\sqrt{(\lambda_1 - \lambda_2)^2 (\lambda_1 - \lambda_3)^2 (\lambda_3 - \lambda_1)^2}}{\sqrt{\lambda_1^2 + \lambda_2^2 + \lambda_3^2}}$$



Artifact Assessment

- Quantitative assessment
  - Unexpected evolution of FA over time
  - Diffusion evolution inconsistent
- Qualitative assessment
  - “blurry” FA images
  - Red Color FA images
  - “Red” Tensors



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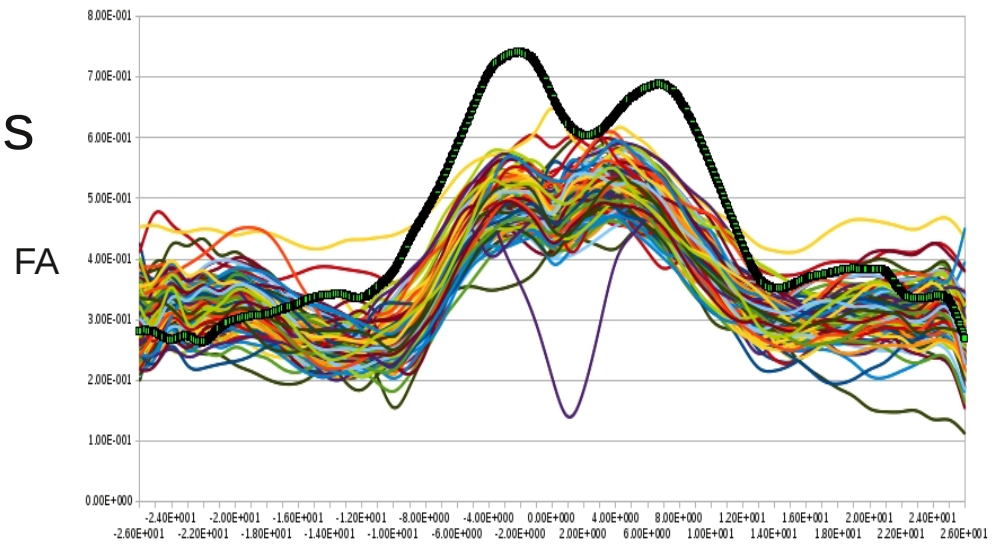
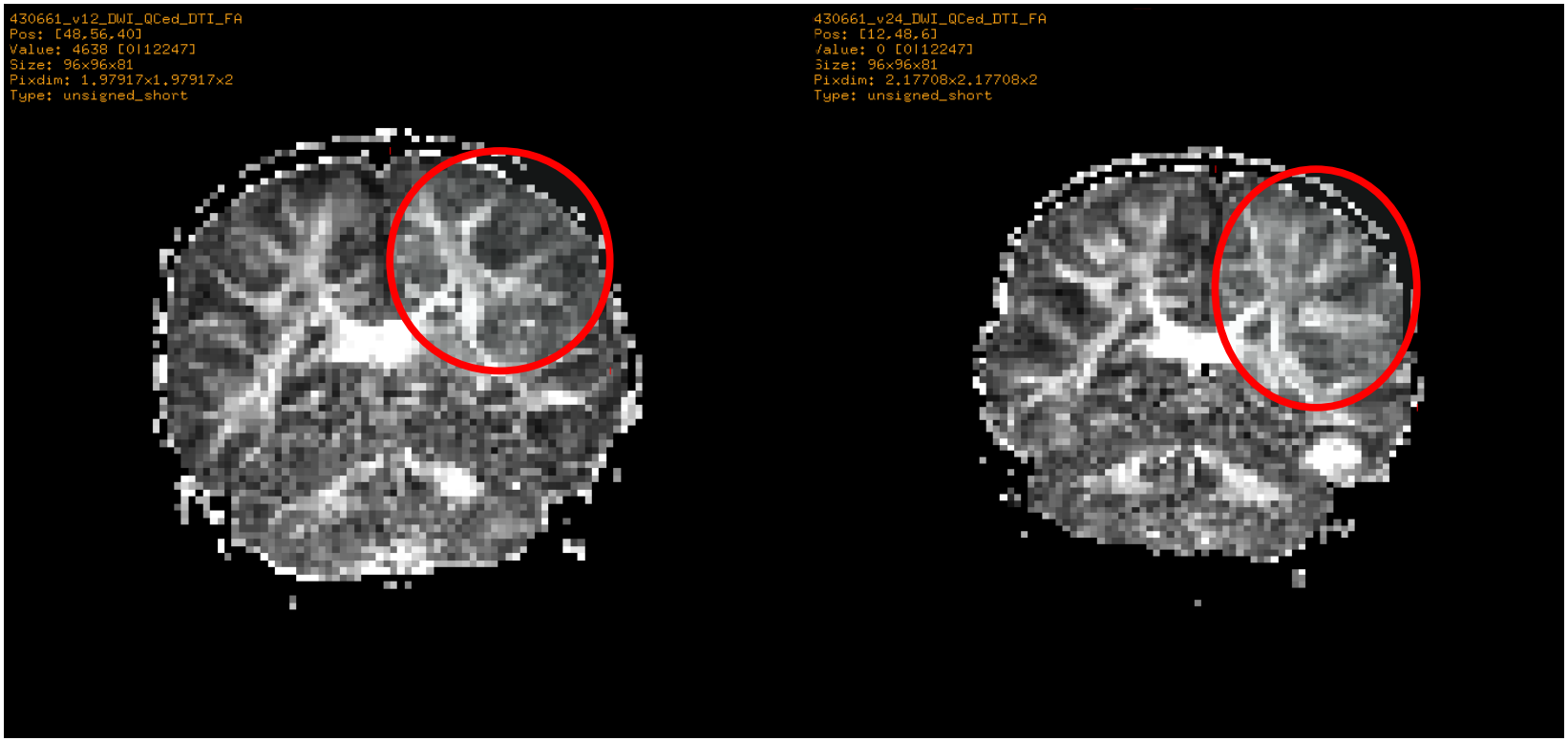


Artifact Assessment

- “blurry” FA images

$$FA = \sqrt{\frac{1}{2}} \frac{\sqrt{(\lambda_1 - \lambda_2)^2 (\lambda_1 - \lambda_3)^2 (\lambda_3 - \lambda_1)^2}}{\sqrt{\lambda_1^2 + \lambda_2^2 + \lambda_3^2}}$$

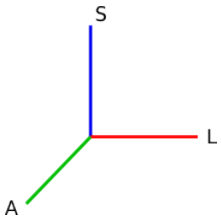


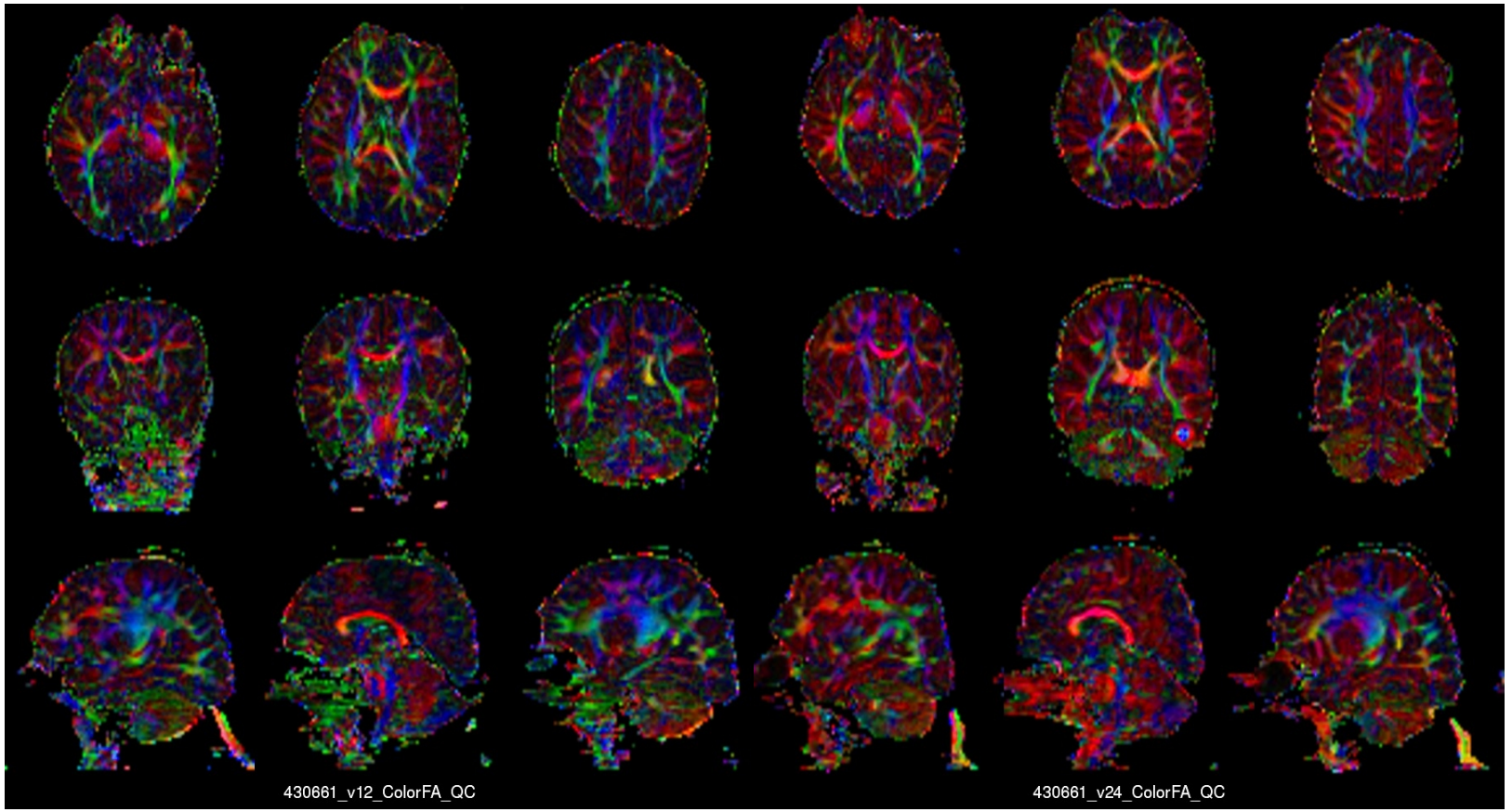
Good case

Bad case

Artifact Assessment

- Red ColorFA images



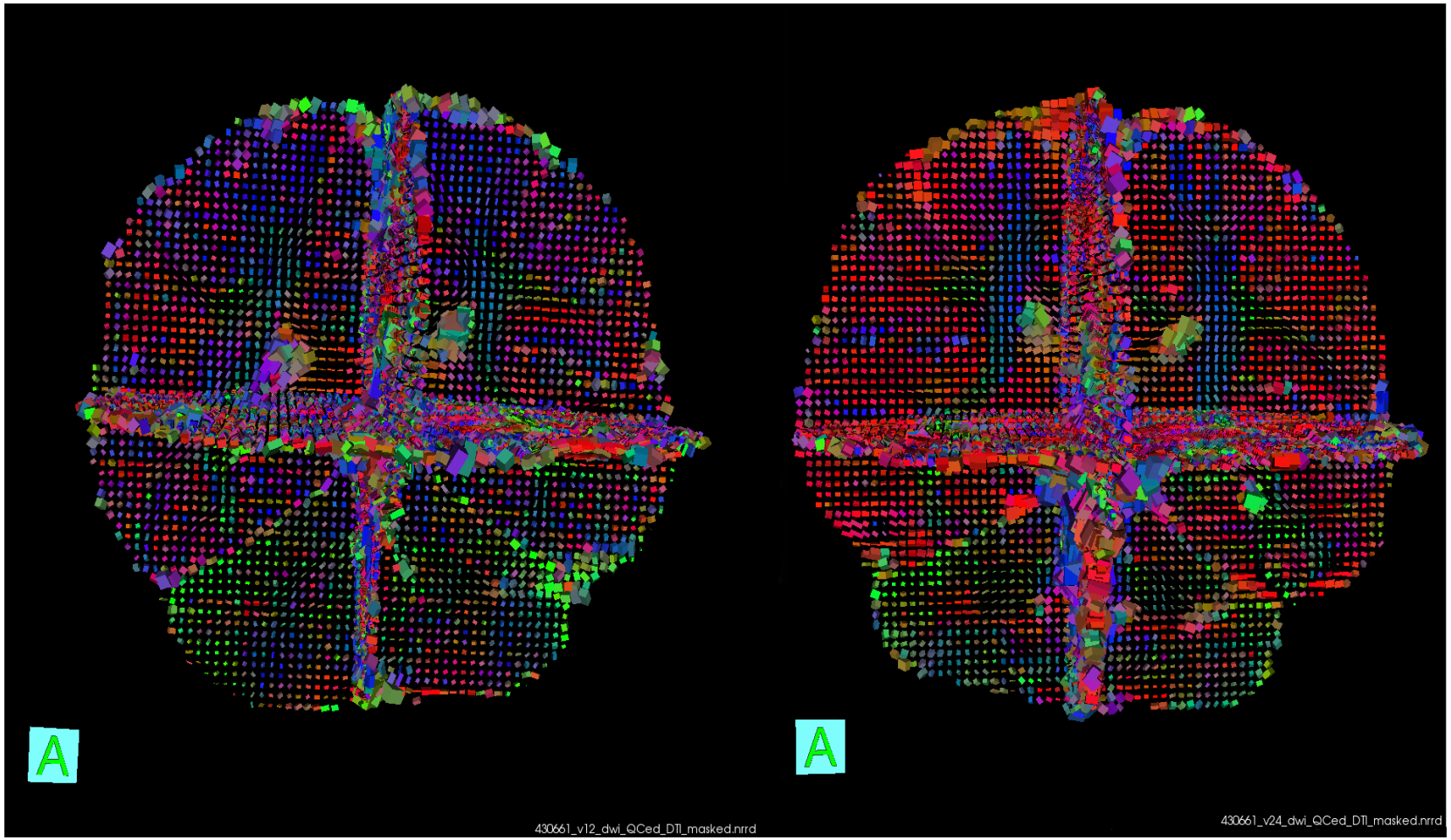


Good case

Bad case

Artifact Assessment

"Red" Tensors



Good case

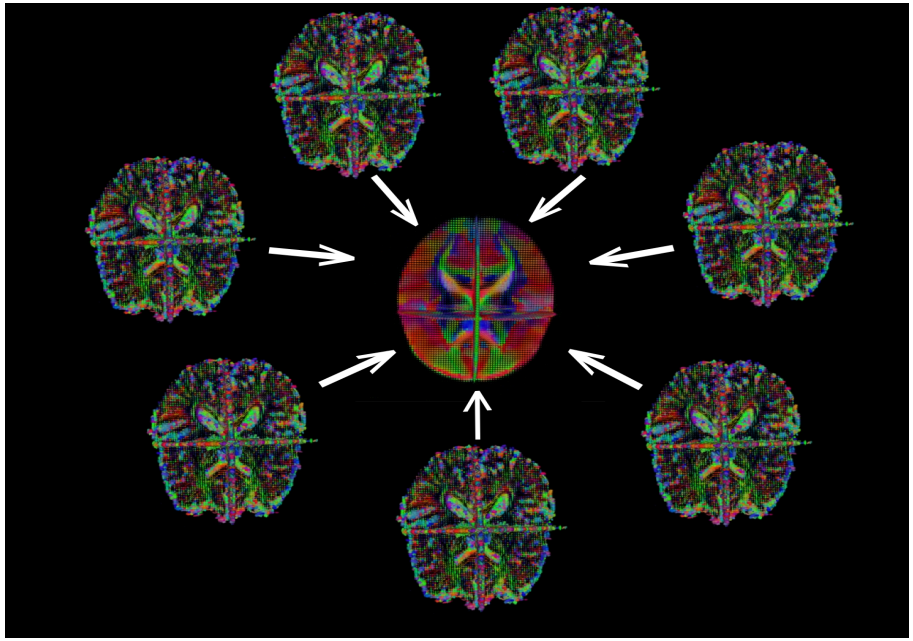
Bad case

Artifact Assessment

- Quantitative assessment
  - Unexpected evolution of FA over time
  - Diffusion evolution inconsistent
- Qualitative assessment
  - “blurry” FA images
  - Red Color FA images
  - “Red” Tensors
- ⇒ Something is wrong but what ?
  - Processing
  - Acquisition

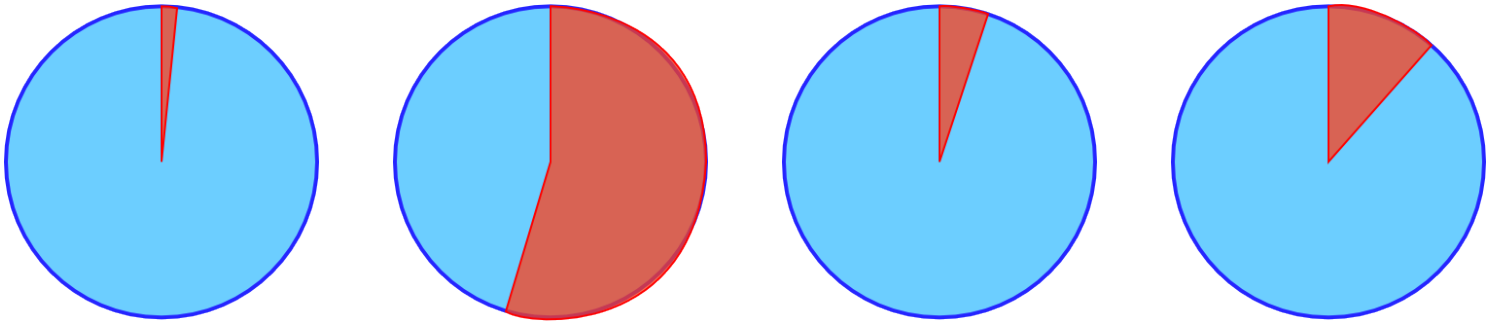
Artifact Consequences

- Wrong calculation of diffusion characteristics
- Poor quality tensors used in atlas building
- Unknown influence of it in atlas building
- Reliability of conclusions based on these data



Statistical Assessment

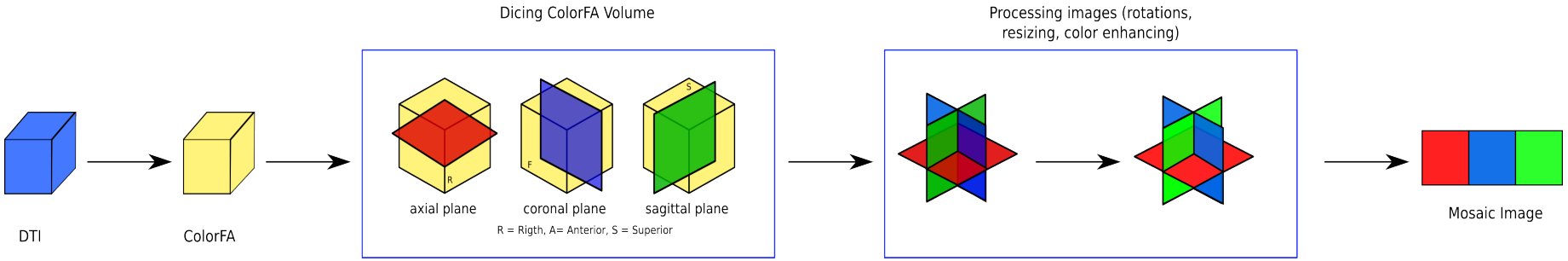
- Our data set is composed of 1200+ DWI sets
- 4 acquisition sites across the US : ACE / IBIS Network
  - University of North Carolina at Chapel Hill
  - University of Washington in Seattle
  - Washington University in St. Louis
  - Children Hospital of Pennsylvania in Philadelphia
- Artifact ratio within the data set :



UNC : 1% SEA : 54% STL : 5% PHI : 12%

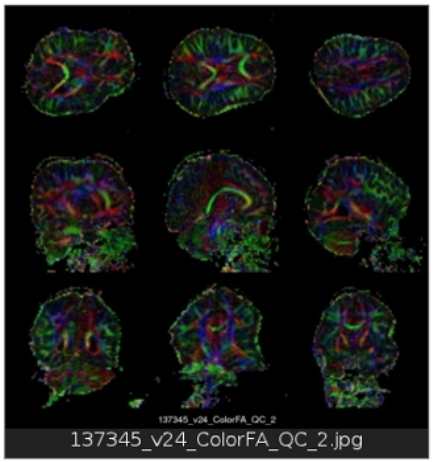
Artifact Detection

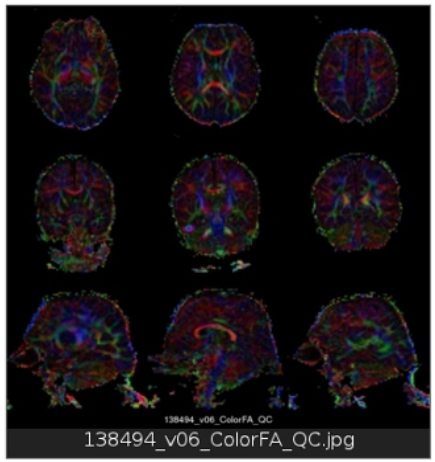
- Visual QC
  - ColorFA-OnlineQuickViewer

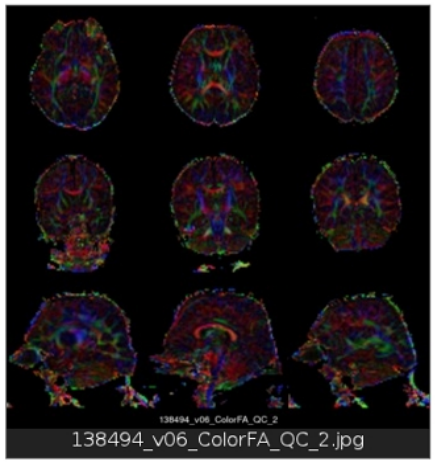


Artifact Detection

- Visual Quality Control


137345_v24_ColorFA_QC_2.jpg


138494_v06_ColorFA_QC.jpg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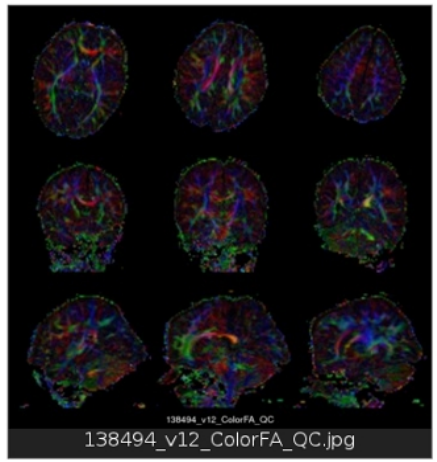
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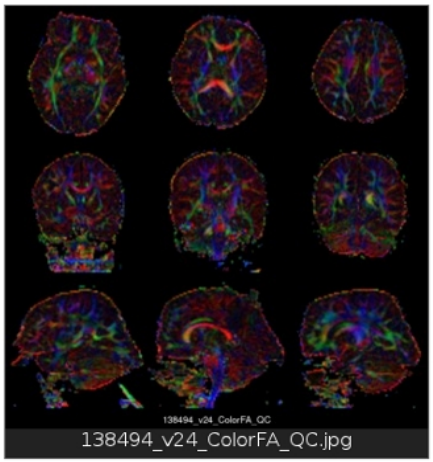
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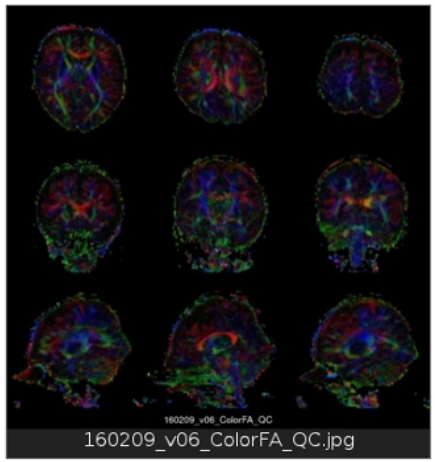
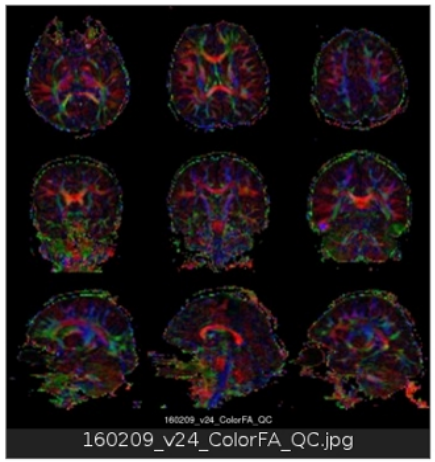

160209_v06_ColorFA_QC.jpg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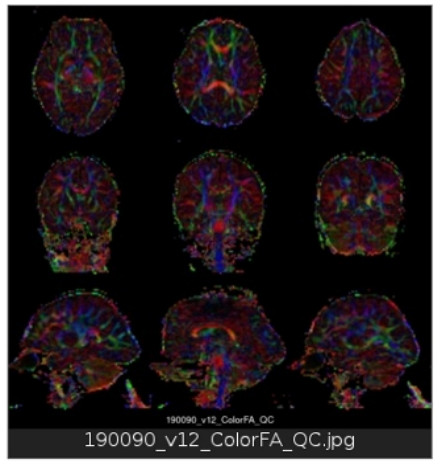
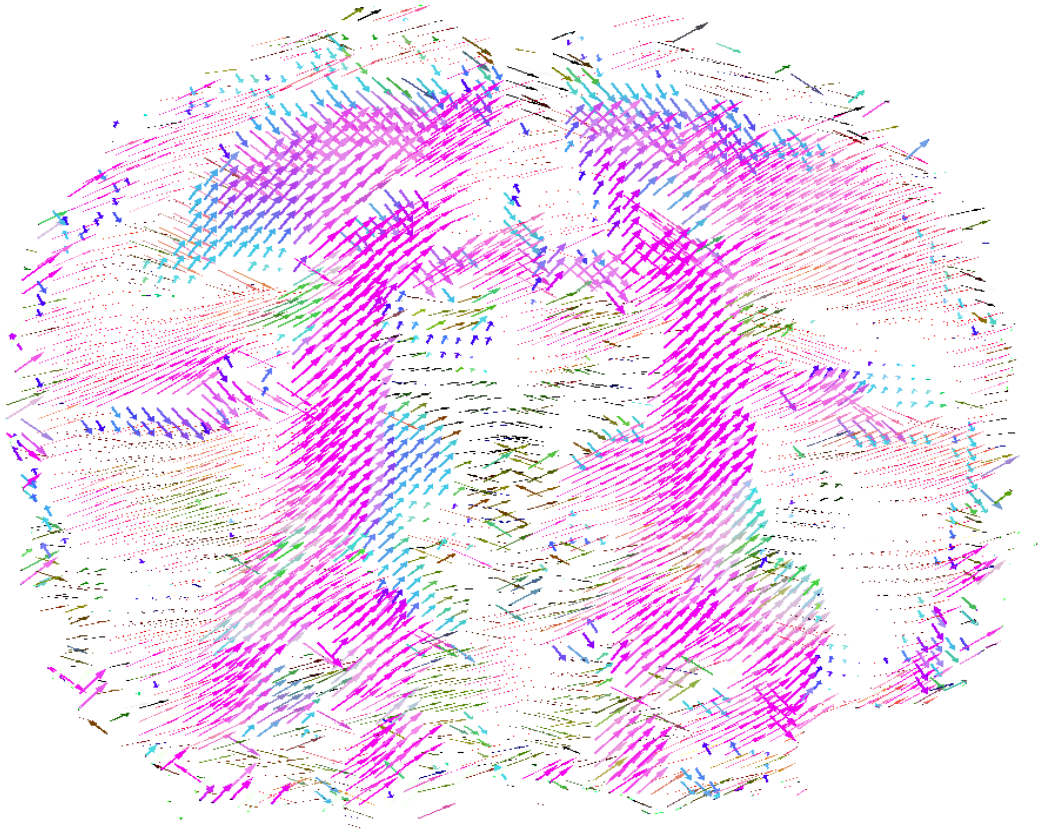
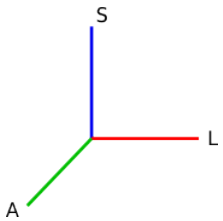

190090_v12_ColorFA_QC.jpg

Artifact Detection

- Principal Direction Space

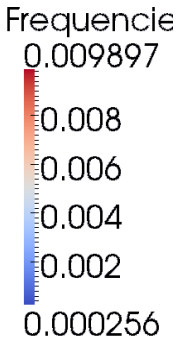


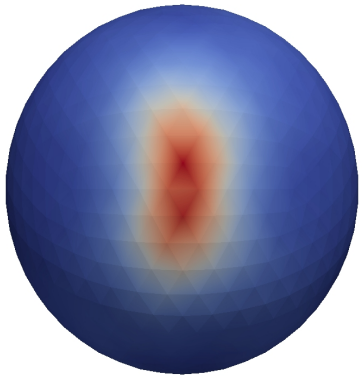


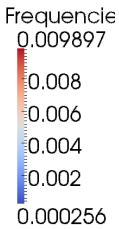
Principal Eigen Vector Field

Artifact Detection

- Principal Direction Spherical Histogram







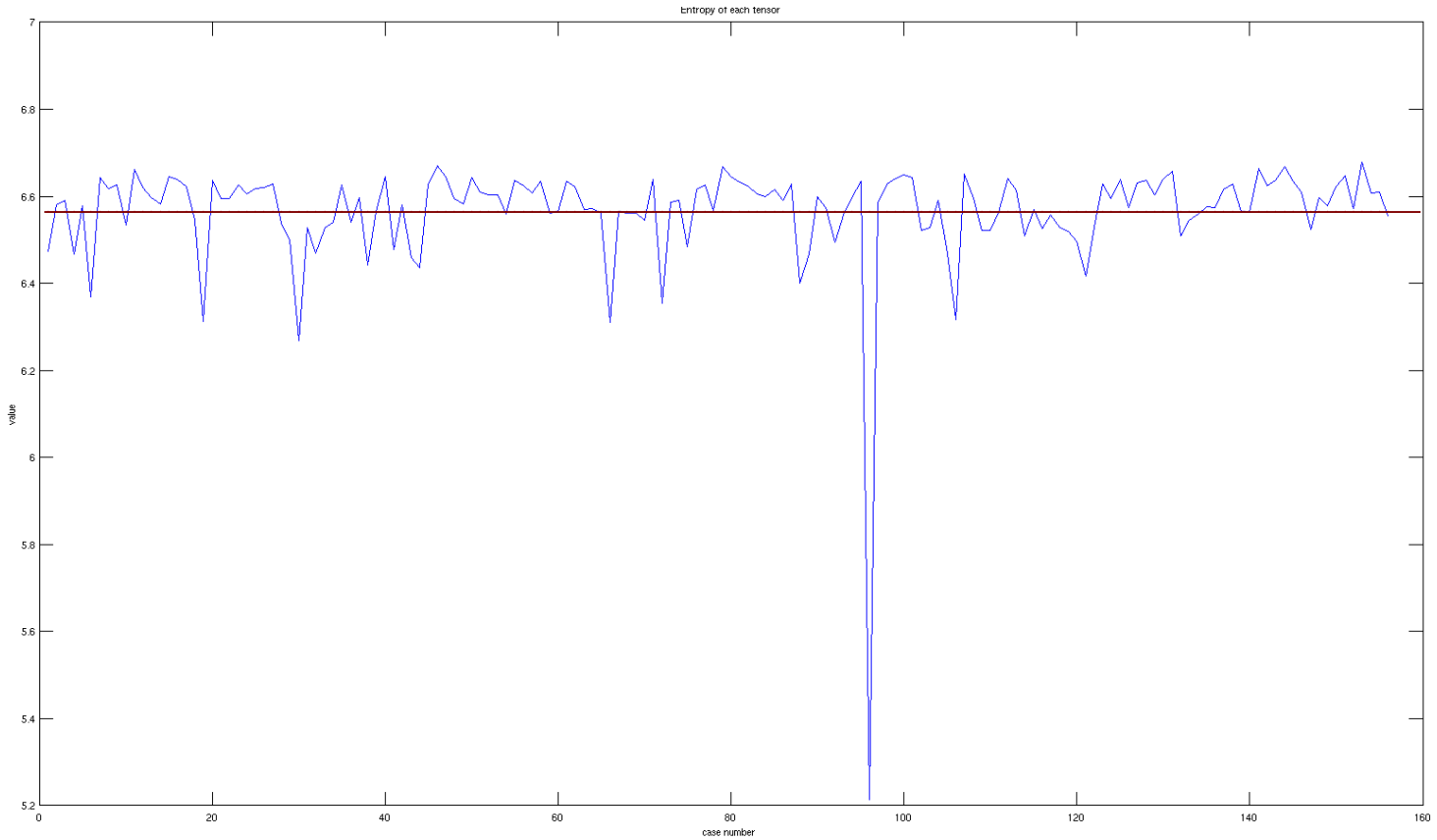
Entropy Based Diffusion Imaging Quality Control via Principal Orientation Distribution : M. Farzinfar et al

Artifact Detection

- Entropy

$$E = -\sum_{i=1}^{K} p_i \log(p_i)$$

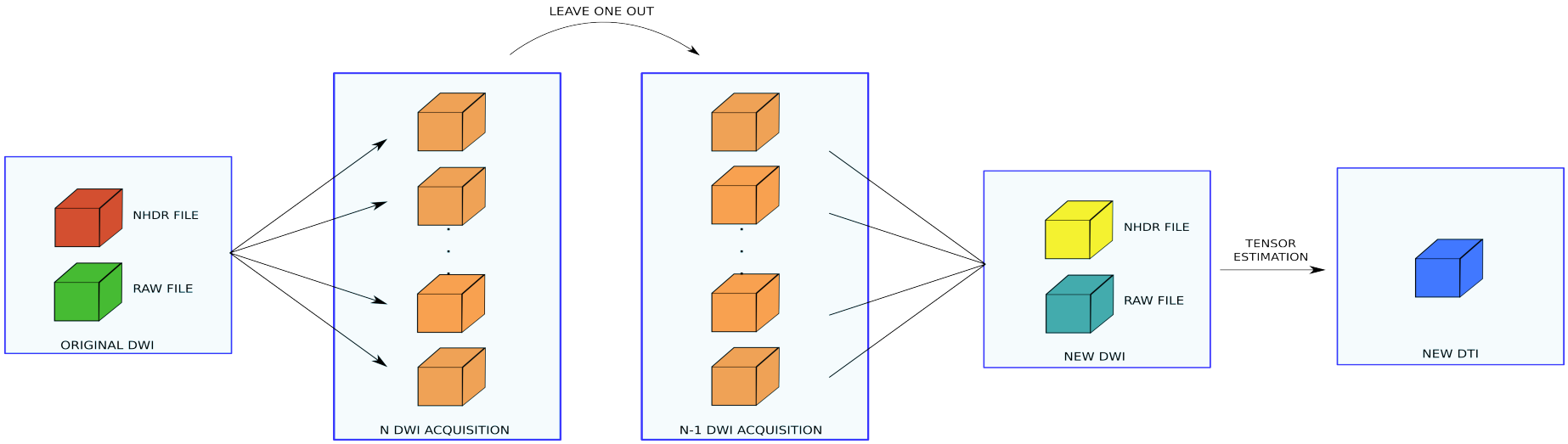
Entropy



case

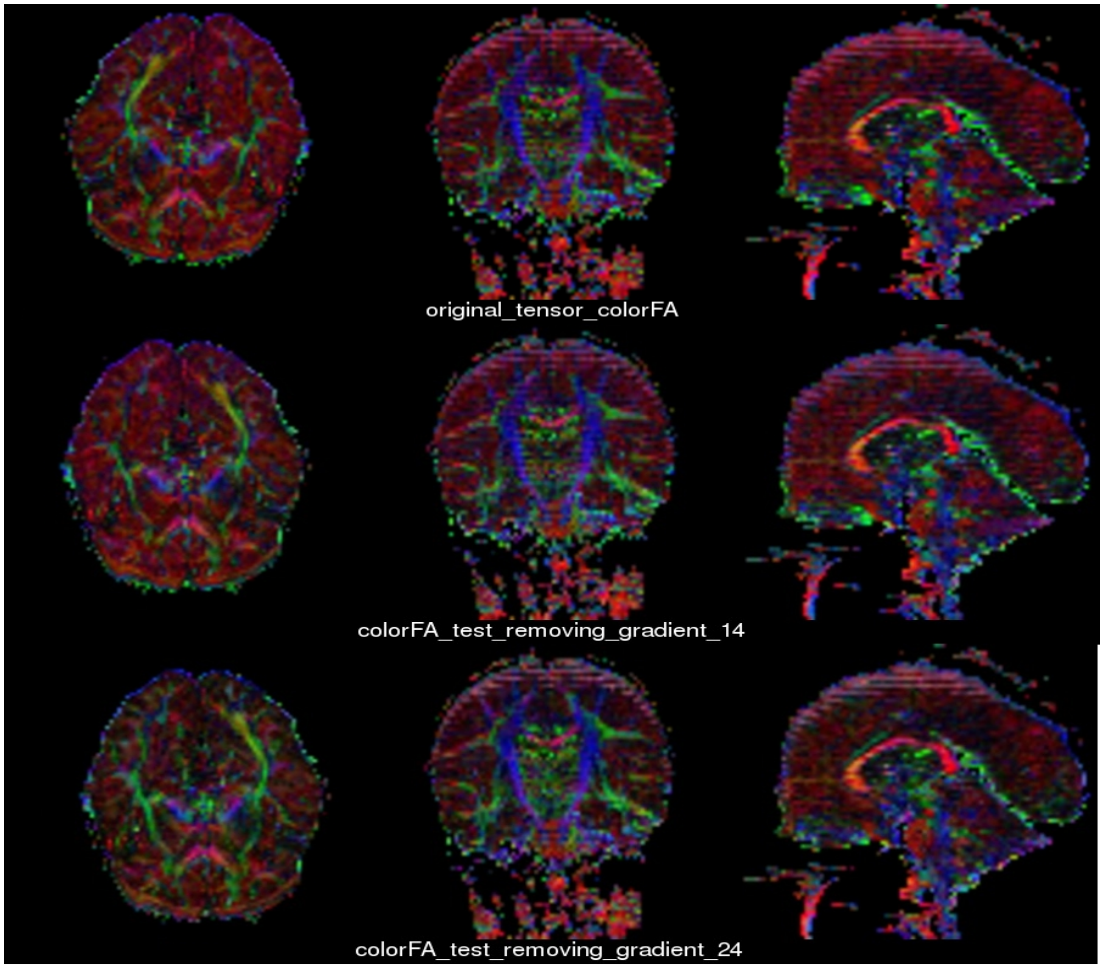
Possible Correction

- The Leave One Out Method (LOO) on DWI set



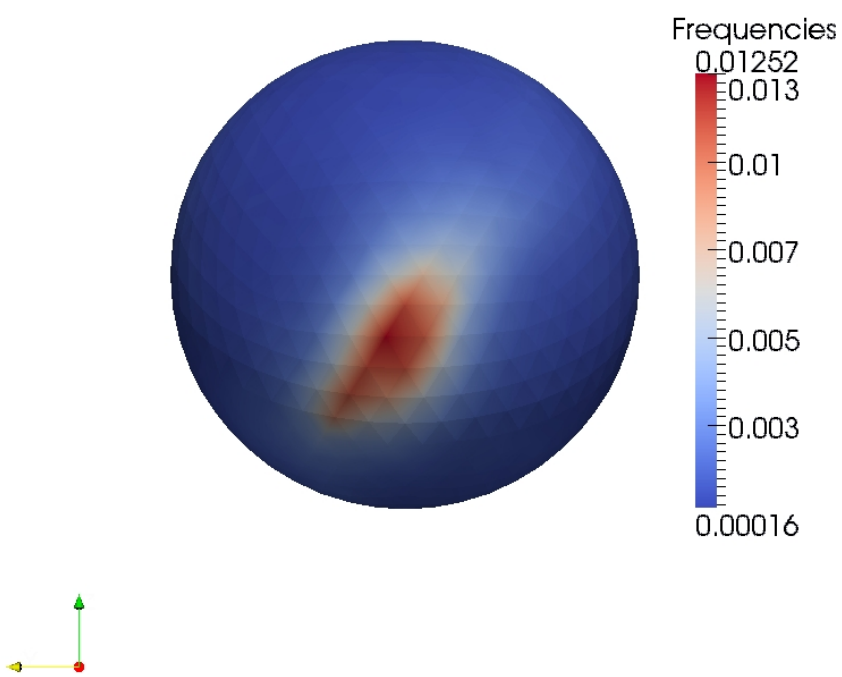
Possible Correction

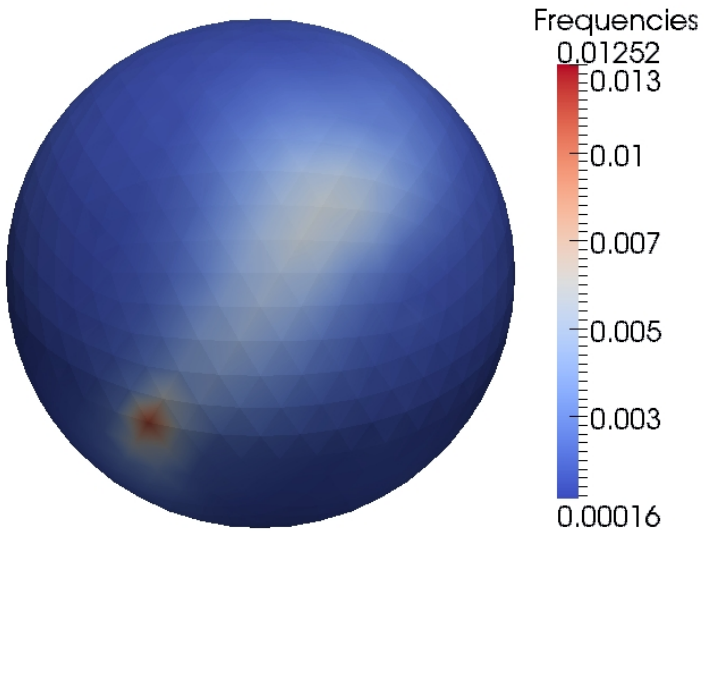
- Leave One Out improved results :



Possible Correction

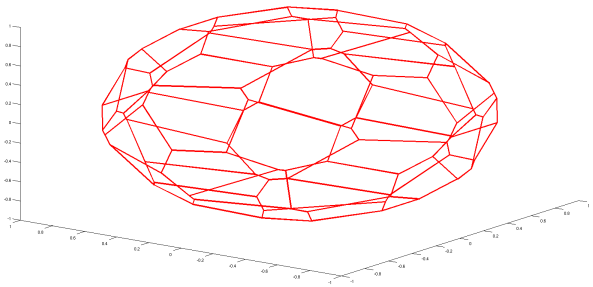
- Analysis with Principle Direction Distribution

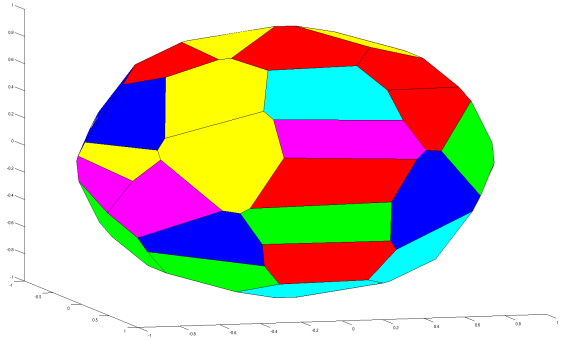




Possible Correction

- Leave Multiple Out Method (LMO)
  - LOO is not generalizable
- Ongoing research
  - Combination of directions depending on patient position
  - Influence of each gradient direction
    - Computation of spherical Voronoi Tessellation





Conclusion

- Identify and characterize directional artifact
- Possible automated detection via entropy
- Possible correction with Leave One / Multiple Out
- Further investigation on acquisition
- Overall Objective: prevent the artifact occurrence

Acknowledgment

- I would like to thank :
  - Dr Guido Gerig
  - Sylvain Gouttard
  - Clement Vachet
  - People in Utah, University of North Carolina and at the Montreal Neurological Institute
  - Everyone for your attention

Questions ?

Tensor Estimation Method

$$S_k = S_0 e^{-b\, g_k^T \boldsymbol{D}\, g_k}$$

$$\ln\left(\frac{S_k}{S_0}\right) = -b\, g_k^T \boldsymbol{D}\, g_k$$