

Towards QSM Reconstruction Challenge 2.0

Acosta-Carbonero, Bilgic, Langkammer, Marques, Meineke,
Milovic, Özbay, Rochefort, Schweser, Shmueli, Tejos

Results 2016 QSM challenge

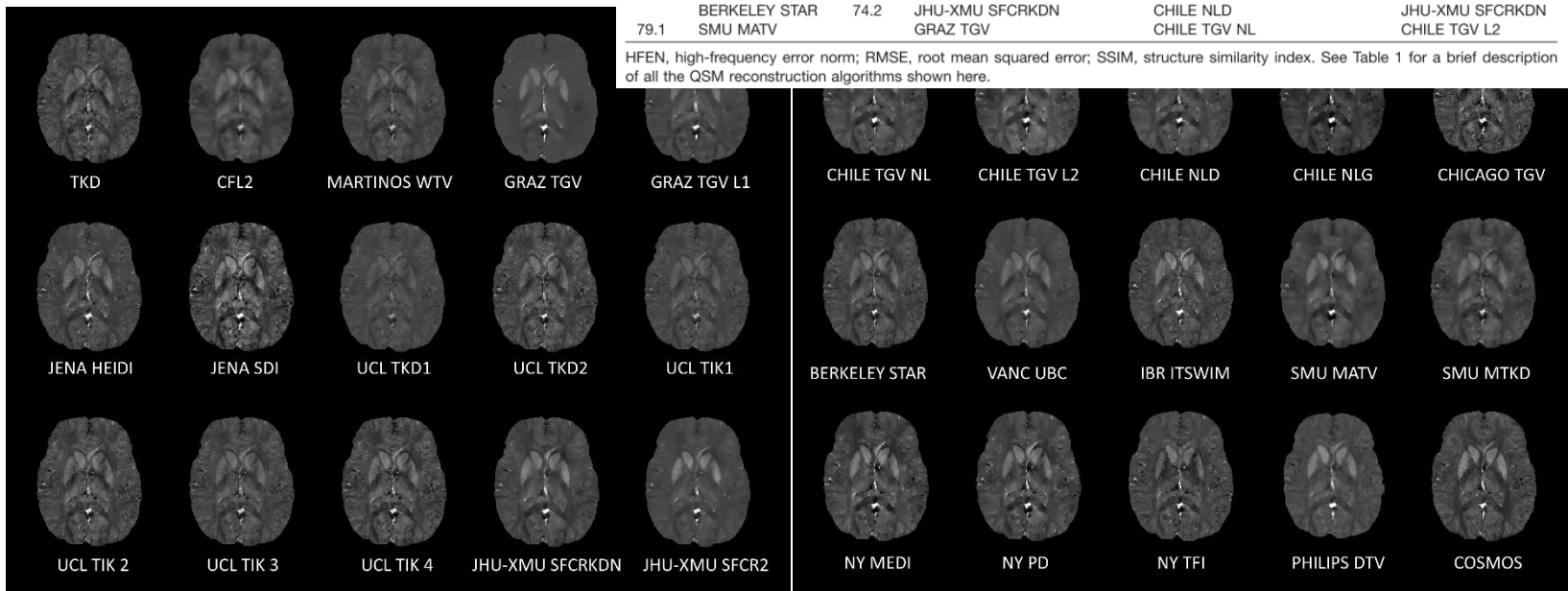
Submissions 2016

Table 2

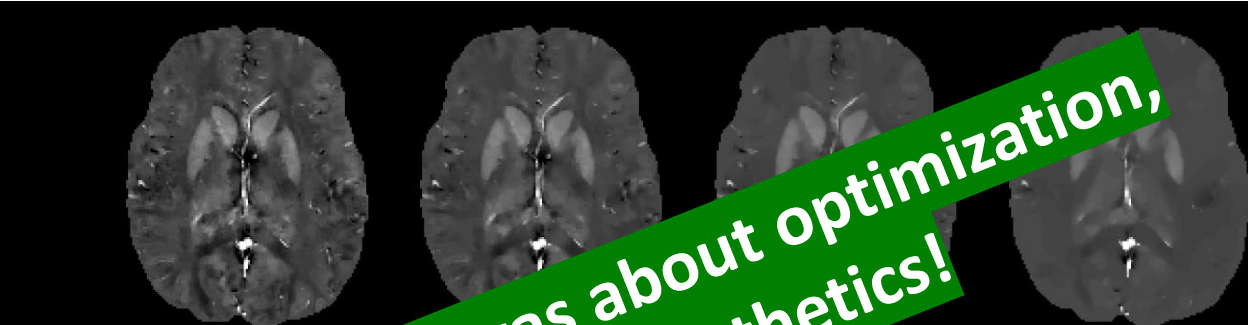
Top 10 Algorithms With the Best Scores in Each Category Evaluated for the QSM Reconstruction Challenge

	RMSE (%)		HFEN (%)		SSIM (0-1)		ROI Error (ppm)
69.0	VANC UBC	63.5	JHU-XMU SFCR2	0.94	JHU-XMU SFCR2	0.016	SMU MATV
70.3	JHU-XMU SFCR2	68.8	GRAZ TGV L1		JHU-XMU SFCRKDN		NY PD
73.6	MARTINOS WTV	68.9	VANC UBC	0.93	NY MEDI	0.017	CHILE TGV NL
74.2	PHILIPS DTV	70.9	PHILIPS DTV		GRAZ TGV		CHILE NLD
74.6	GRAZ TGV L1	71.8	SMU MATV	0.87	GRAZ TGV L1		SMU MTKD
75.2	UCL TIK 1	73.1	UCL TIK 1	0.84	CHILE TGV L2	0.018	CFL2
76.6	UCL TKD 1	73.6	MARTINOS WTV		NY TFI		UCL TIK 2
77.5	GRAZ TGV	74.1	IBR ITSWIM	0.83	JENA HEIDI		UCL TIK 4
	BERKELEY STAR	74.2	JHU-XMU SFCRKDN		CHILE NLD		JHU-XMU SFCRKDN
79.1	SMU MATV		GRAZ TGV		CHILE TGV NL		CHILE TGV L2

HFEN, high-frequency error norm; RMSE, root mean squared error; SSIM, structure similarity index. See Table 1 for a brief description of all the QSM reconstruction algorithms shown here.



- Metrics for QSM



$\alpha_0 =$	0.0005	0.001	0.002	0.004
$RMSE =$	97.9	81.2	77.5	
$SSIM =$	91.3	93.5	94.2	92.9
$ROI Error =$	0.022	0.020	0.019	0.021

QSM challenge 2016 was about optimization, not about image aesthetics!

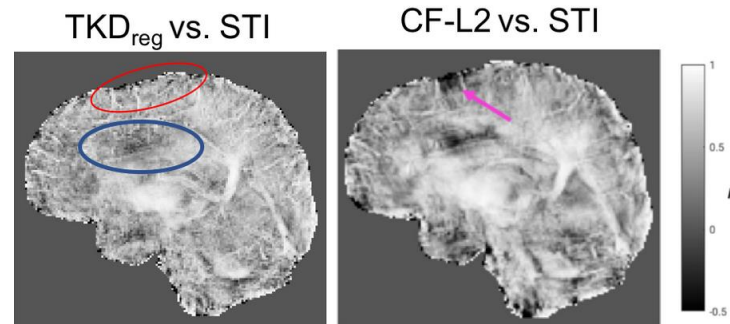
- **Lessons learned:**
 - The forward field generated by the ground truth was different from the field offered.
 - Susceptibility anisotropy and micro-structure were not accounted for.
 - Optimal reconstruction is dependent on the resolution, SNR and level of artifacts of the data set.
 - Quality metrics used are “relative”.
- Benchmark GRE data set (12 orientations) freely available.
- Encourages critical discussions about current limitations in QSM.

Ideas for QSM challenge 2.0

- **Ideas collected since QSM challenge 2016:**
 - QSM challenge 1.5
 - Patient vs. control clinical dataset
 - Cortical QSM
 - Oximetric evaluationEffect of noise
 - QSM + advanced diffusion MRI
 - Synthetic phantom data (+ forward simulation)
 - Pushing the frontiers (outside brain / at boundaries)
 - Multi-centric/multi-vendors/test-retest/multi-resolution/multi-acquisition/multi-field protocols QSM reproducibility

- **QSM challenge 1.5**

- Data
 - More datasets
 - Varying resolution / SNR
- New evaluation metrics
 - Proposed: MI, CC, Δ RMSE
 - Correlation analysis (#0193)
 - SI-SSIM (#2205)
 - 2 –stage evaluation:
first 1 orientation, then ground truth



Evaluation metrics calculated between proposed methods vs. ground-truth (STI)

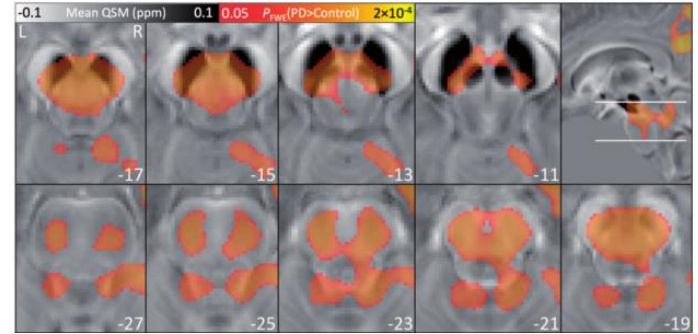
	RMSE	HFEN	SSIM	ROI	mean r
CF-L2	81.23	75.49	0.81	0.018	0.51
TKD	85.73	81.50	0.78	0.022	0.53
TKD _{reg}	84.28	79.12	0.79	0.022	0.54
COSMOS	50.05	50.51	0.92	0.013	0.81

- **However:**

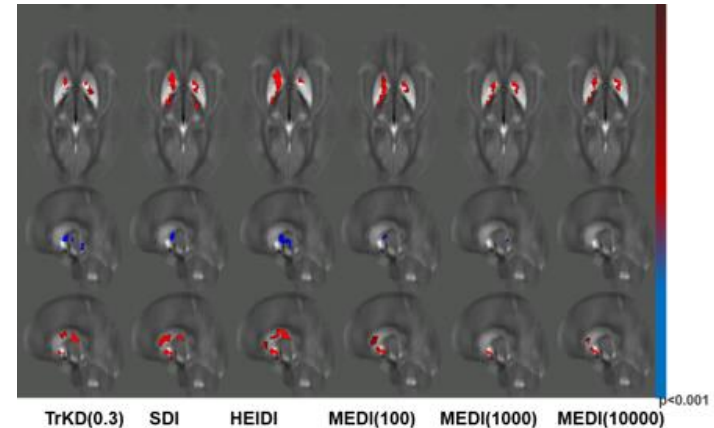
- Already ongoing in current papers

- **Patient vs. control data**
 - Real world clinical setup:
 - E.g. 50 Parkinson's vs. 50 controls
 - QSM images calculated by contestants
 - Standardized voxel based analysis

- **How to interpret the results?!?**
 - What is better?
 - P-values? Cluster sizes?
 - Comparison with histology?



Acosta-Cabronero, 2016, Brain



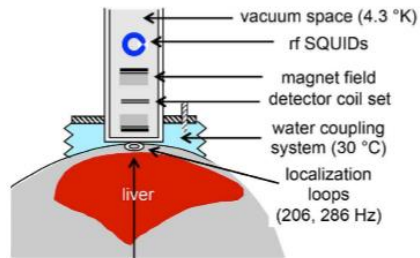
Choudhary #2218, ISMRM 2018

- **Cortical QSM**

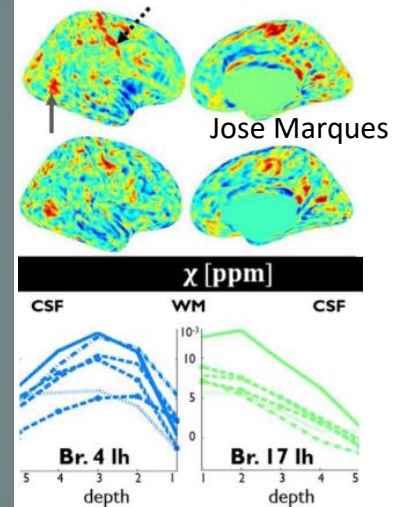
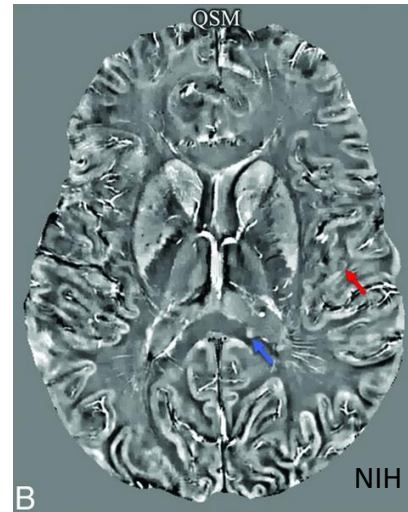
- Highly relevant for diseases like Alzheimer's and fQSM
- “Some” pixels are “lost”
- Requires high resolutions and multi-orientation, best at 7 Tesla:

- **SQUID & oximetric evaluation**

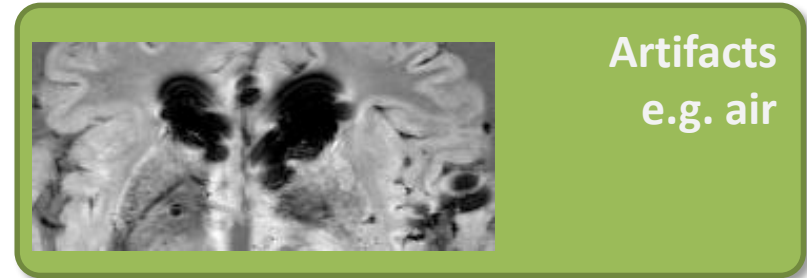
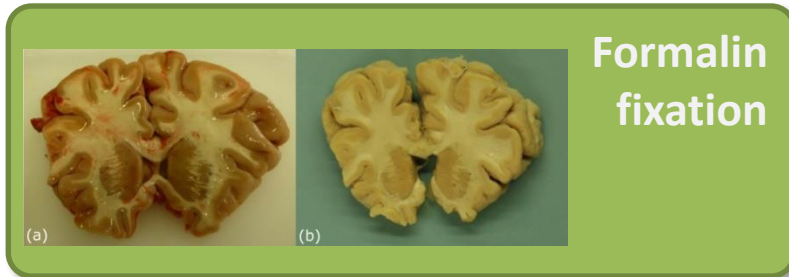
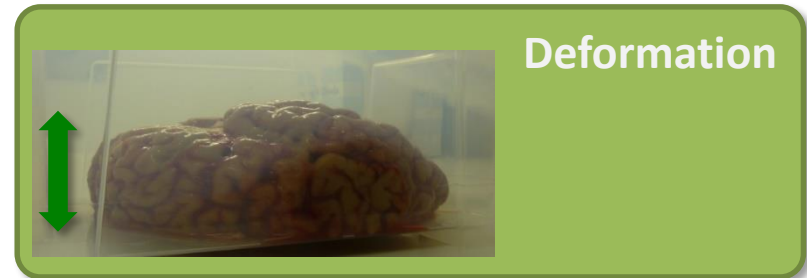
- Complementary methods:



Samir Sharma



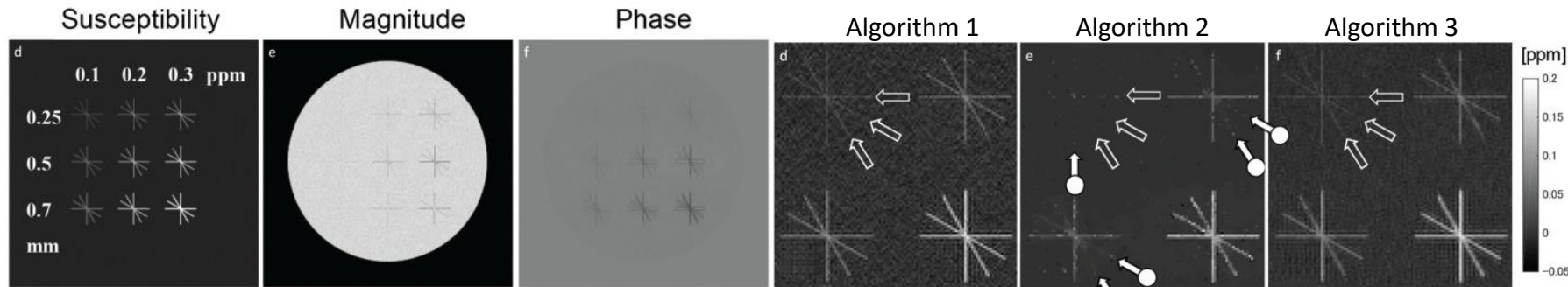
- Post mortem validation



Deoxygenated blood, edema, ...*

- **Multi-resolution**
 - Same scan with different resolution
 - 0.3mm^3 , 0.5mm^3 , 0.7mm^3 , 1mm^3 , $1\times 1\times 2\text{mm}^3$, $1\times 1\times 4\text{mm}^3$
- **Effect of SNR to inversion**
 - Denoising capabilities of the algorithms
- **QSM + “Advanced” diffusion MRI**
 - DTI main fiber direction seems not sufficient
 - HARDI/DSI/Multi-Tensor model?
 - Synthetic data? Phantom from DWI?
 - Post mortem phantom?

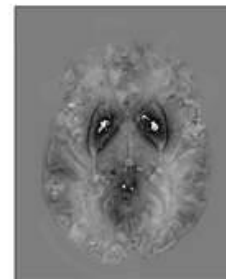
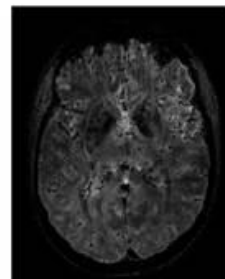
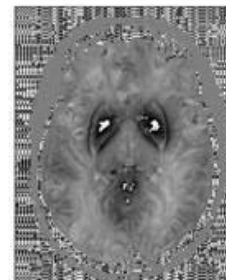
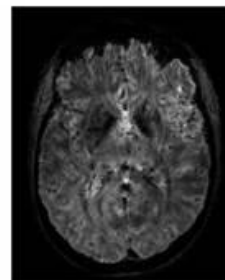
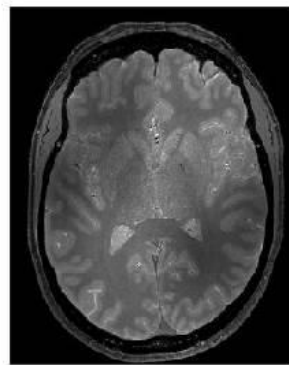
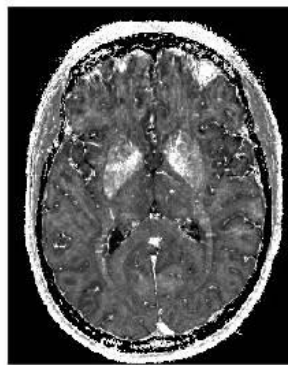
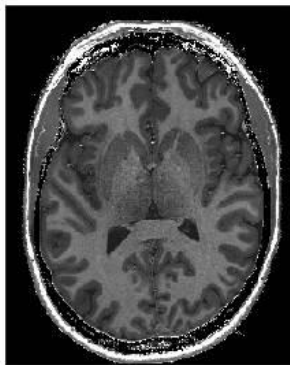
- **Synthetic data**
 - Ground truth!
 - Realistic geometry derived from GM/WM/CSF
 - White matter anisotropy?
 - E.g. Cornell phantom, Wharton paper...
 - Including synthetic vessels, calcifications, hemorrhages, and more.



- **Modelling synthetic data**
 - 7T data (R1, R2*, M0, 0.6 mm isotropic from one single scan [1])
 - Main tissue compartments segmentation (GM/WM/CSF/calc/air/fat)
 - Synthetic susceptibility maps
 - Non piece-wise constant models (variability from R1 and R2*)
 - Trying to match the measured field map
 - Forward field calculation with Bloch equations to provide
 - GRE with specified TR/TE/FA with 0.6, 0.9 and 1.2 mm isotropic resolution
 - Removes microstructure and anisotropic effects from the evaluation process
 - Secondary aim:
 - Freely available, realistic brain contrast forward generator
 - DWI (1.5mm iso) to add microstructure effects a posteriori [2]

[1] M. Caan et al, Proc. ISMRM, 2018, [2] S. Wharton et al, MRM, 2015

- **Modeling synthetic data**
 - Currently in development (Lead José Marques)



Roadmap for QSM challenge 2.0

- **September 2018**
 - Final call for challenge ideas
- **November 2018**
 - Discussions and preparation of data and code framework
- **May 2019 (ISMRRM Montreal)**
 - Release of data and instructions
- **September 2019 (QSM Workshop in Seoul)**
 - Submission deadline

Thank you!

Please participate with your ideas!

Slides and infos are available at www.qsm.rocks