Accelerated z-Spectrum Imaging

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Declaration of Financial Interests or Relationships

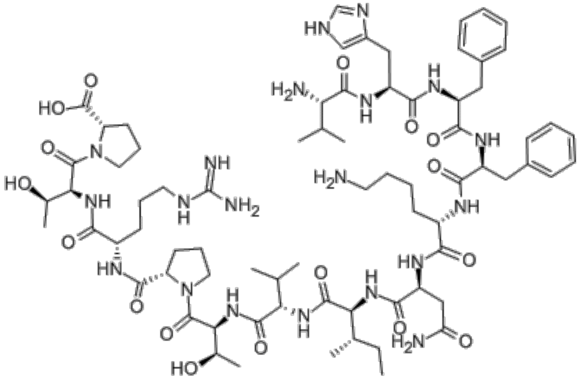
Speaker Name: **Melany Mclean**

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

Motivation

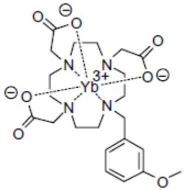
- Conventional MRI signal **does not directly detect macromolecules**
  - Sub-millisecond T2
- **z-Spectrum** based methods enhance sensitivity to macromolecules (qMT)[1] and labile protons (CEST)[2]
- z-Spectrum imaging methods limited by long acquisition times
- **Compressed-sensing** and **parallel imaging** combined to accelerate z-spectrum
  - 600 - 60,000 Hz range

Macromolecule



Myelin basic protein [3]

CEST Agent



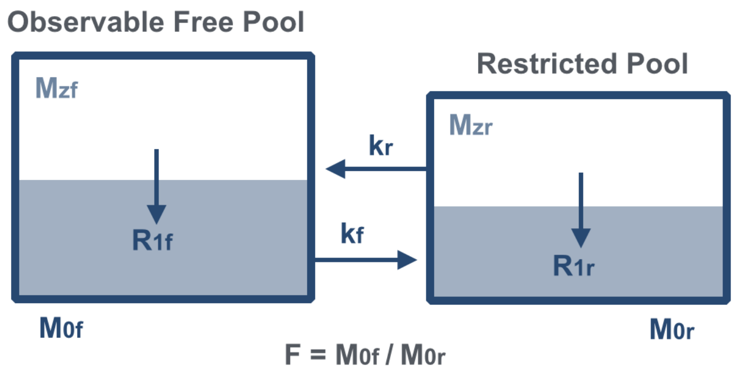
Diamagnetic, responsive to lactate [4]

[1] Kuncharczyk et. al. Radiology, 1994; [2] Wolff et.al. J. Magn. Reson, 1990
[3] Chemical Book, 2007; [4] Daryaei et. al. Res. Rep. Nucl. Med, 2015

Methods: z-Spectrum

- **Two-pool tissue model:** directly observable nuclei (free) and macromolecular nuclei (restricted) [1]
- Selective saturation of restricted pool creates observable changes in free pool via **magnetization transfer**
- SPGR imaging sequence
- Restricted pool **saturation pulse**:
  - Fermi pulse shape
  - 2 Pulse powers (FA = 180°, 360°)
  - 15 Offset frequencies (0.6 - 60 kHz)

Two-Pool Tissue Model (qMT)

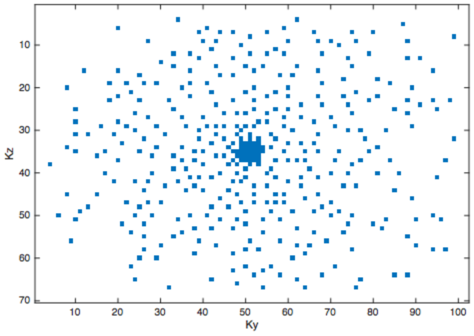


[1] Henkelman et. al. Magn Reson Med, 1993

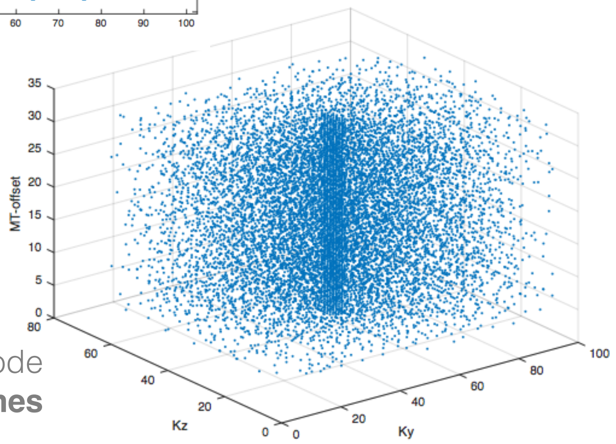
Methods: Undersampling

- **Retrospective undersampling** performed on fully sampled k-space data
- <u>3 subjects</u>, <u>4 versions</u> per rate
- Sampling Strategy:
  - **Random undersampling** enforces incoherent signal aliasing [1]
  - **Fully sampled core** (10% of samples)
  - Probability decays as a **power** (square) from centre [2]
  - **Poisson disc** sampling with variable disc size

16x Undersampled



Frequency encode lines chosen from **one volume**



Frequency encode lines in **all volumes**

[1] Lustig et. al. Magn Reson Med, 2007; [2] Zijlstra et. al. Invest Radiol, 2015

Methods: SparseSENSE

Minimize:

$$f(m) = ||F_u S m - y||_2^2 + \lambda_1 ||m - m_r||_1 + \lambda_2 ||\Psi m||_1 + \lambda_3 ||T_\nu m||_1$$

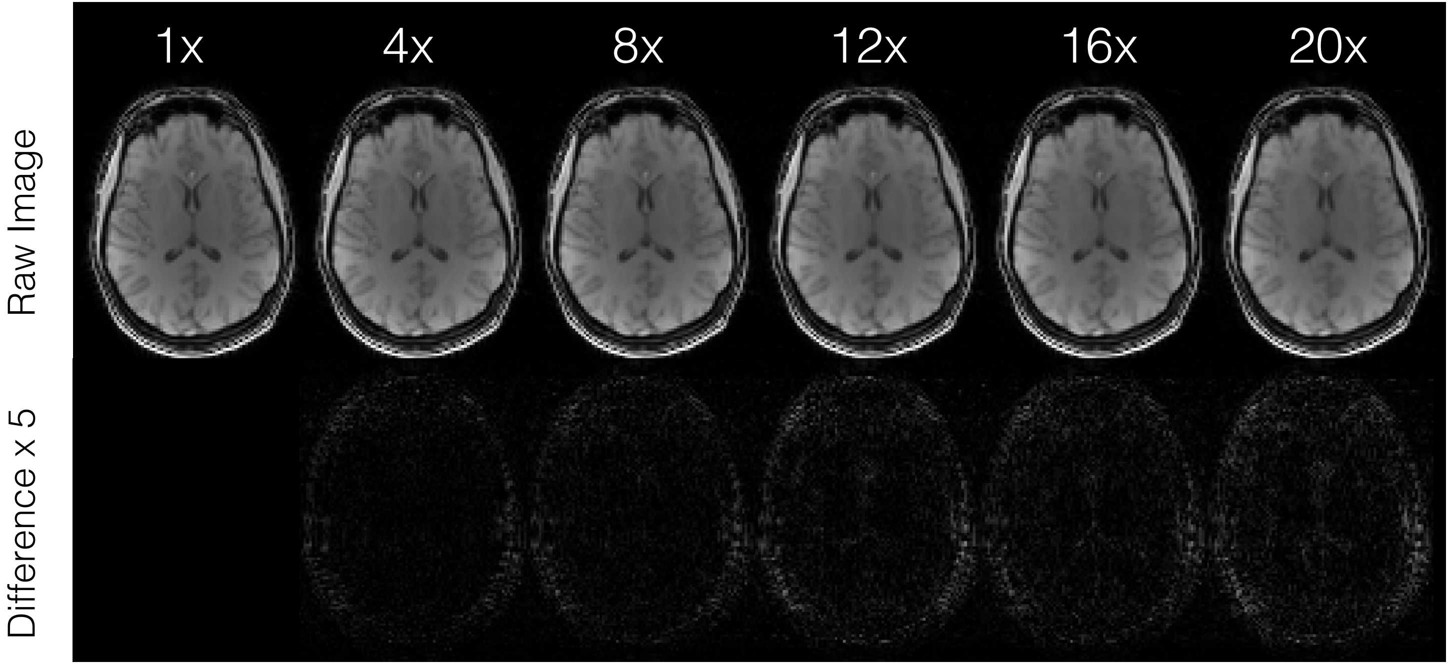
$\lambda_1 = 0.001, \lambda_2 = 0.0005, \lambda_3 = 0.0001$

m - final image, y - undersampled k-space

- **Enforce consistency** with acquired k-space. S is the **coil sensitivity** operator for parallel imaging
- **Local low rank** reference image (mr) promotes simple behaviour in the MT-offset frequency dimension
- **Wavelet transform** and **total variation** enforce spatial sparsity

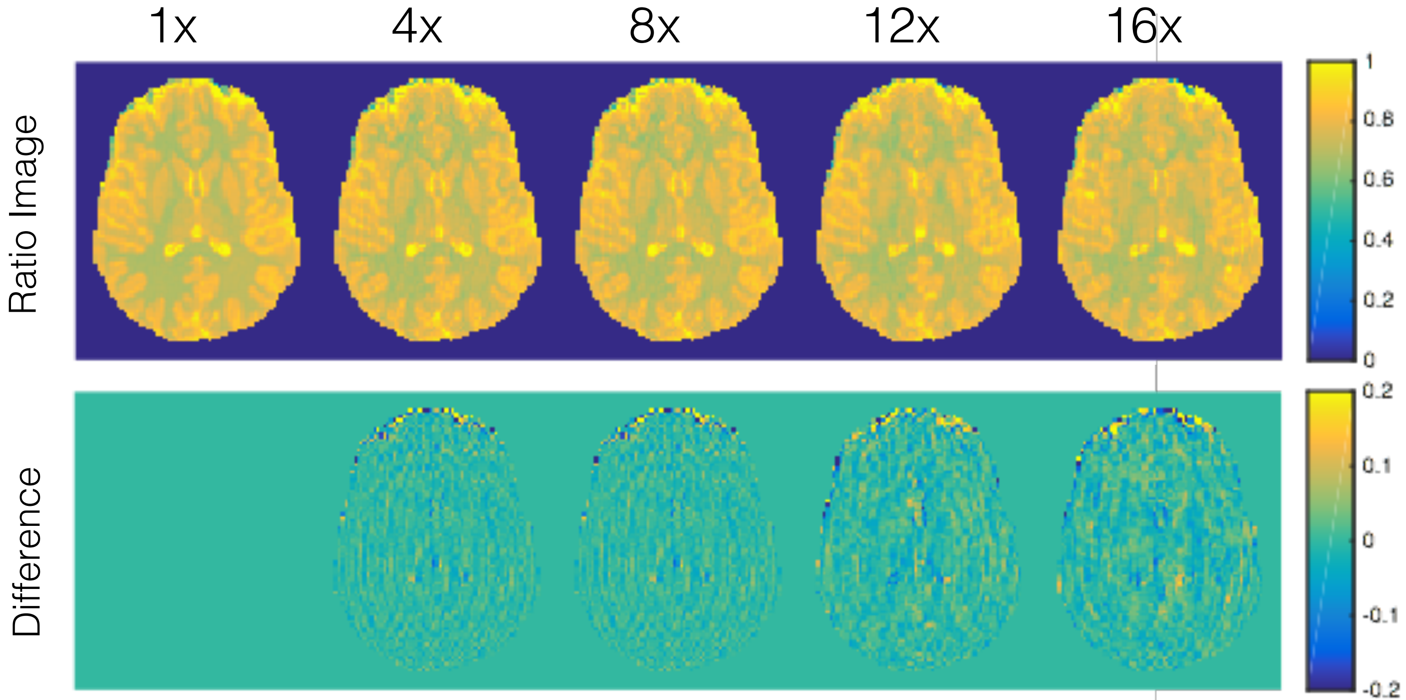
SparseSENSE: Liu et. al. Magn Reson Med, 2008

Results: Raw Images



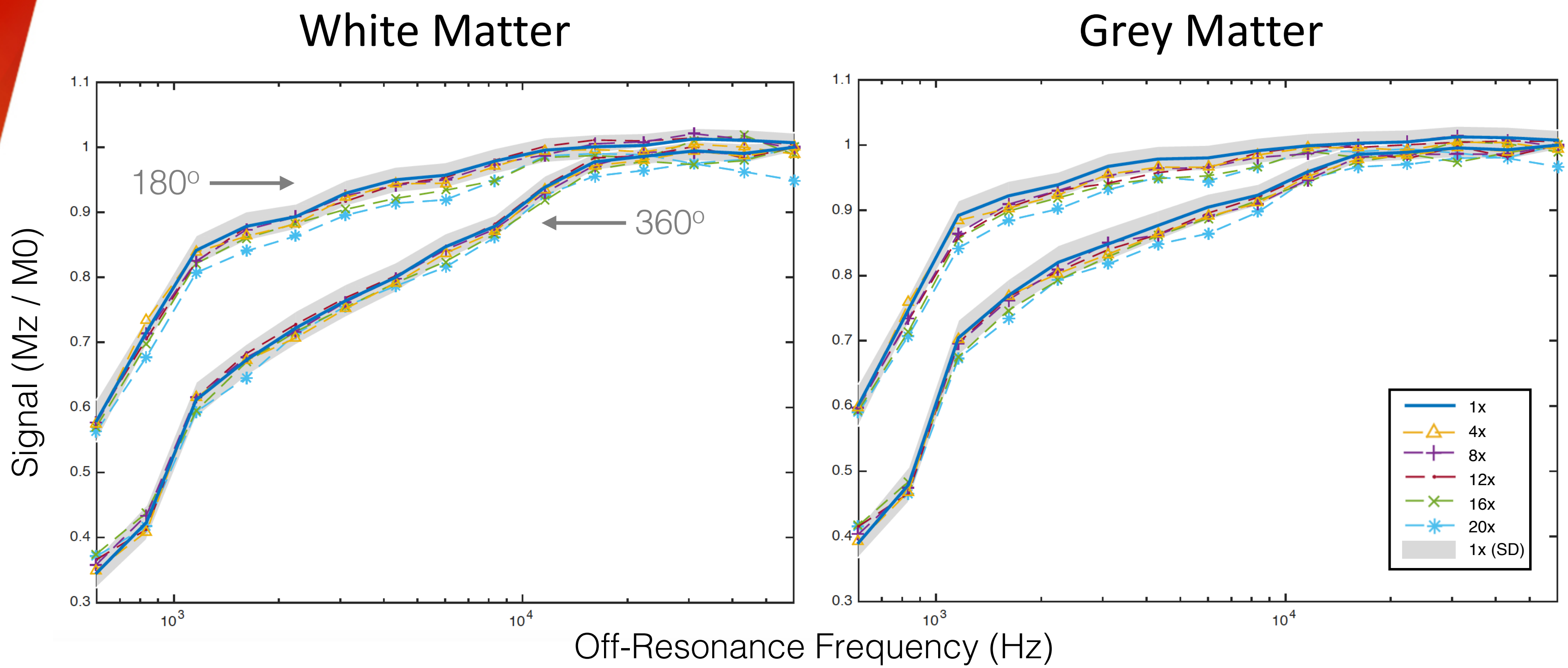
- Top row: Accelerated magnetization transfer image
- Bottom row: Absolute difference images **scaled by a factor of 5**
- Saturation pulse FA = 180^{o}; Offset frequency = 51.8 kHz

Results: Ratio Images



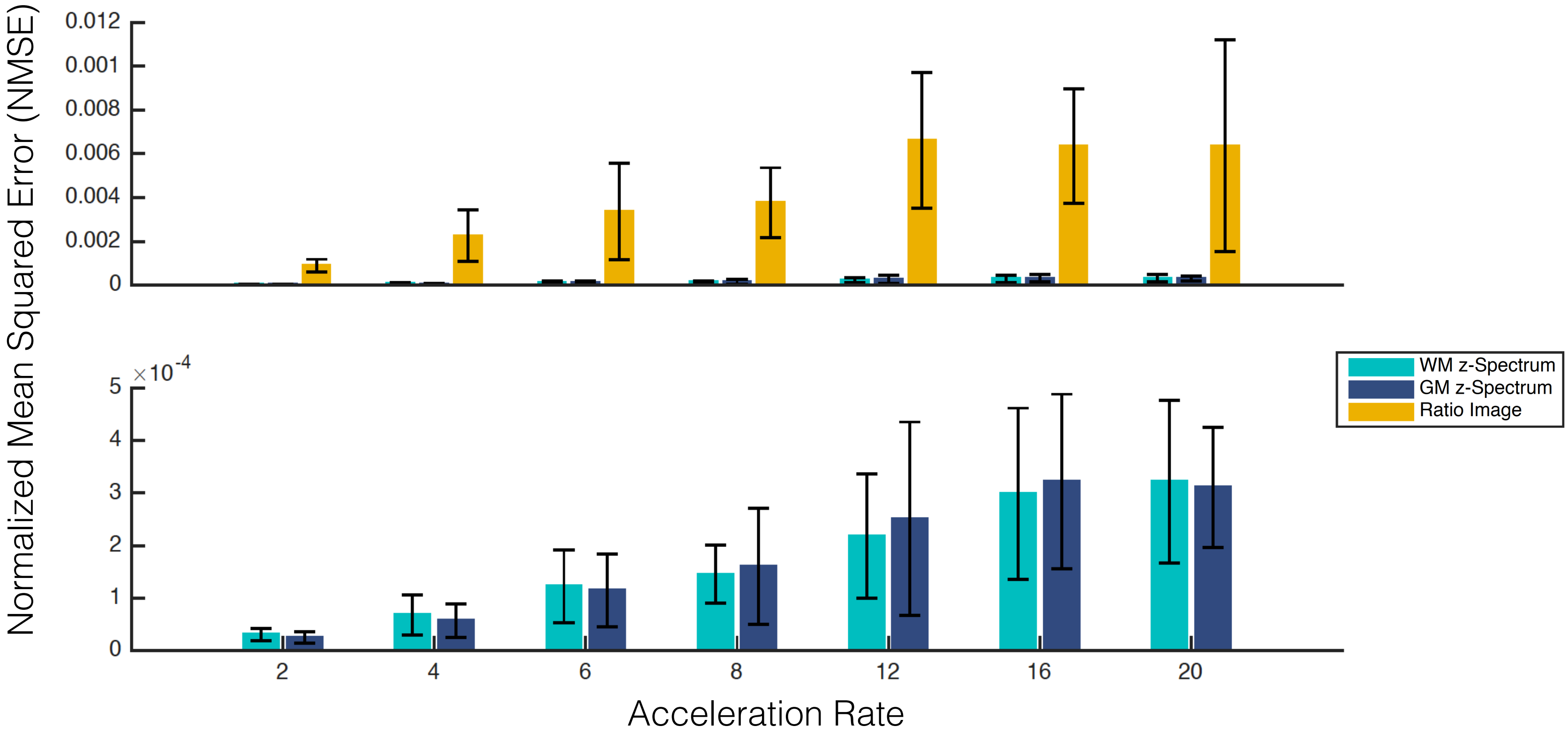
- Top row: Saturation ratio from baseline (Mz / M0)
- Bottom Row: Difference from fully-sampled
- Saturation pulse FA = 360°; Offset frequency = 1.93 kHz

Results: z-Spectra



Rate	1	4	8	12	16	20
WM std. dev.	0.020	0.037	0.042	0.049	0.055	0.057
GM std. dev.	0.035	0.051	0.058	0.069	0.068	0.076

Results: Quantitative Analysis



Conclusion

- **Key Findings**:
  - Raw images and z-spectra are more robust to acceleration than ratio images
  - z-Spectra fall within fully-sampled Std. Dev. up to an **acceleration factor of 16**
  - Underestimation of z-spectra at high acceleration rates
- **Impact**:
  - Prospective acceleration (R=16): qMT scan time reduced **from 38 min to 2.5 min**
  - z-Spectrum imaging techniques such as CEST and qMT may become more clinically applicable