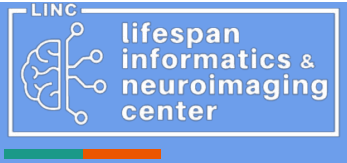


Imaging Brain Iron with Quantitative Susceptibility Mapping (QSM)

Thiti (Nob) Premrudeepreechacharn

Outline

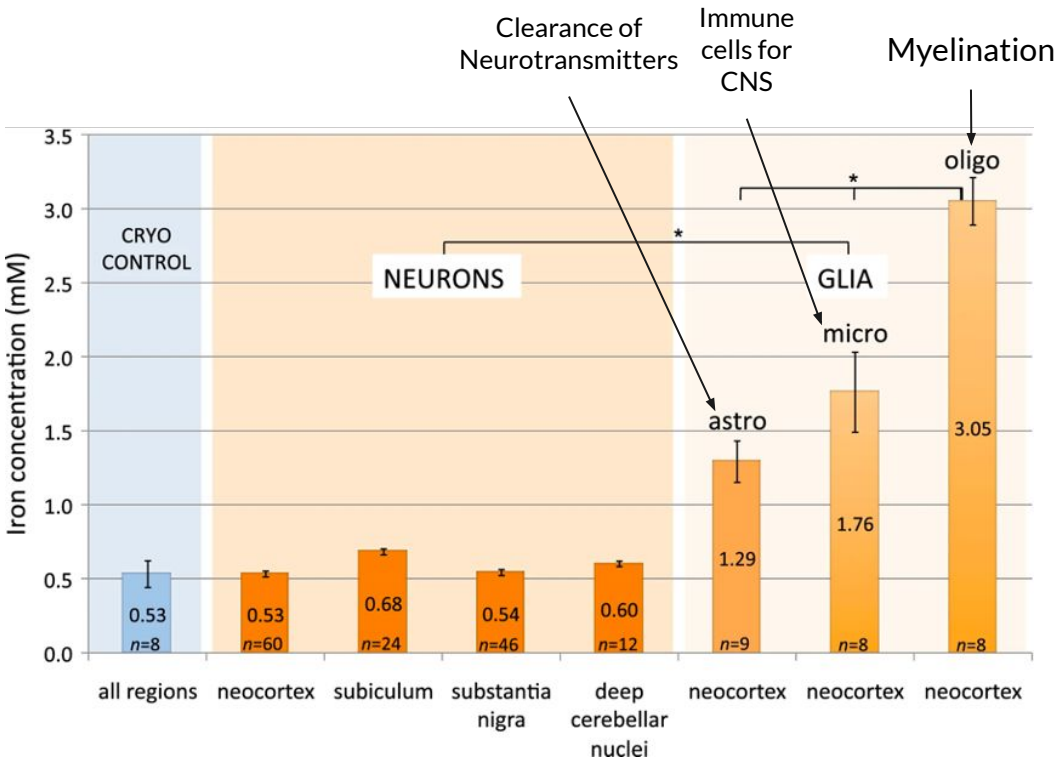
- Why study iron in the brain
- How can QSM help us with studying iron in the brain
- Current workflow ⇒ Custom end-to-end pipeline

What is brain iron?

Iron is important for numerous processes in brain

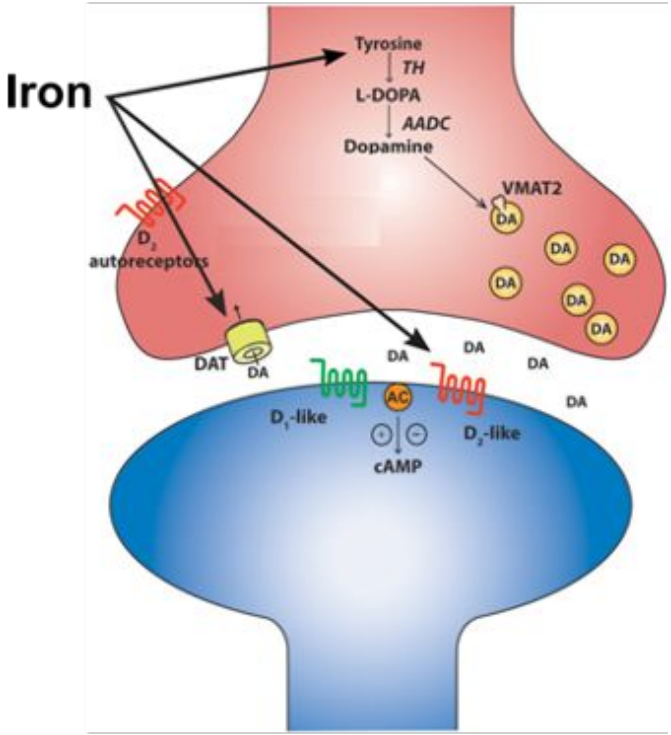
Iron is an essential co-factor for a number of biochemical and enzymatic reactions that are critical to brain function.

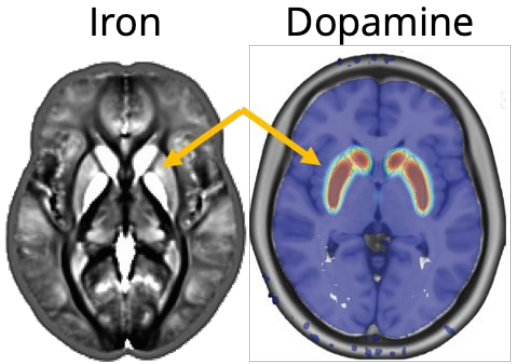
- Neurotransmitter synthesis
- Myelination
- Metabolism



Reinert et al., 2019 *BMC Neuroscience*

Iron is tied to dopaminergic system in both physiological and pathological cases

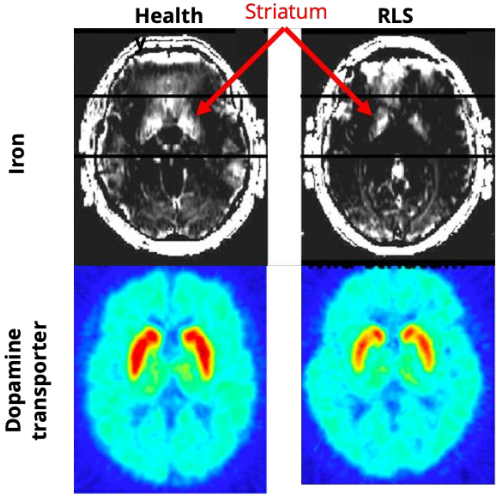




Larsen & Luna, *Dev. Cogn. Neurosci. 2015*

Larsen et al., *Nature Communications 2020*

Larsen et al., *Journal of Neuroscience 2020*



Haba-Rubio et al., 2005

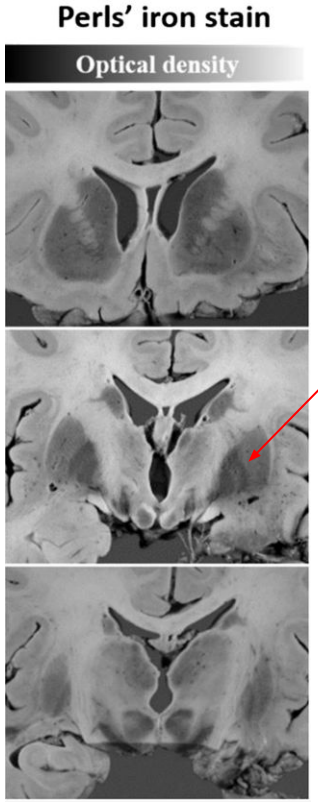
Earley et al., 2011

Outline

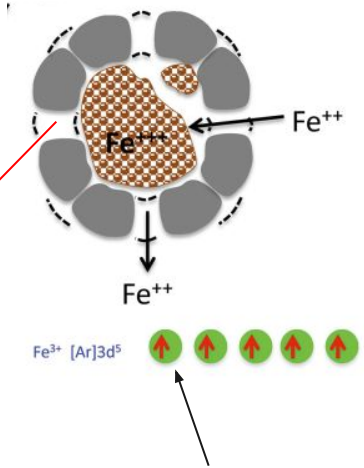
- Why study iron in the brain
- How can QSM help us with studying iron in the brain
- Current workflow ⇒ Custom end-to-end pipeline

How can we measure iron with MRI?

Iron is paramagnetic



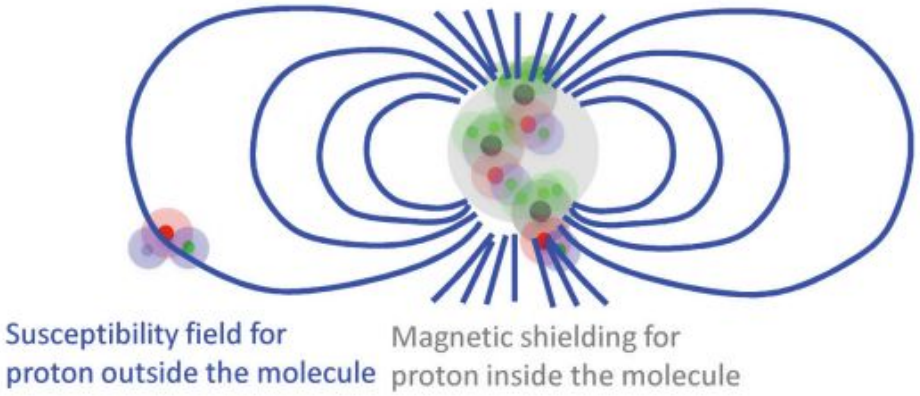
Ferritin ⇒ Paramagnetic



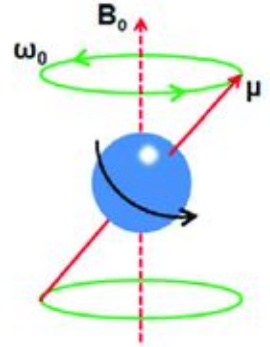
Unpaired electrons of Fe^{3+} within Ferritin ⇒ strong paramagnetism

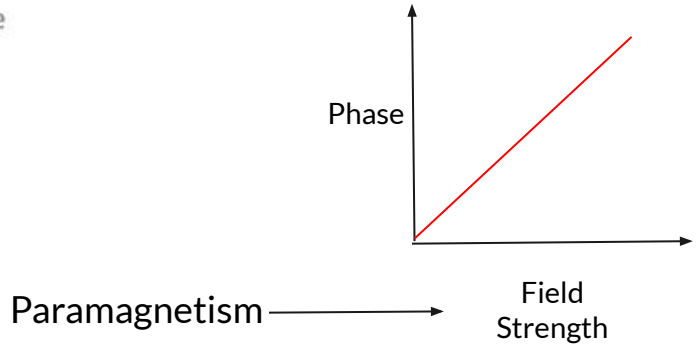
Wang and Liu, *Magn Reson Med*. 2015

Tissue magnetization generates its own magnetic field affecting MRI signal

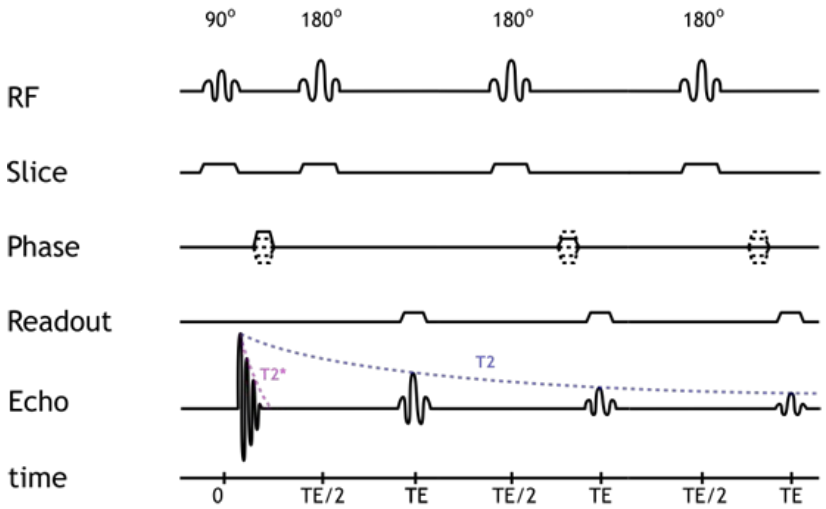


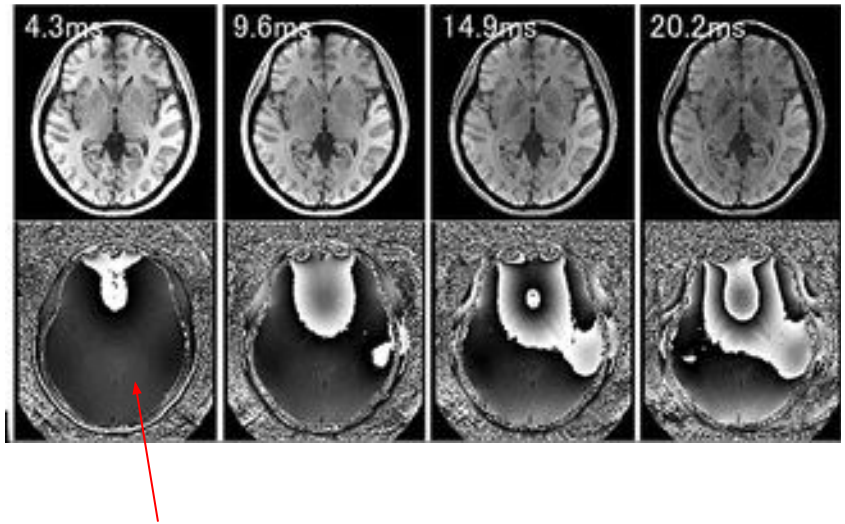
Wang and Liu, *Magn Reson Med*. 2015





Quantitative Susceptibility Mapping (QSM) starts with estimation of total field from MRI phase image

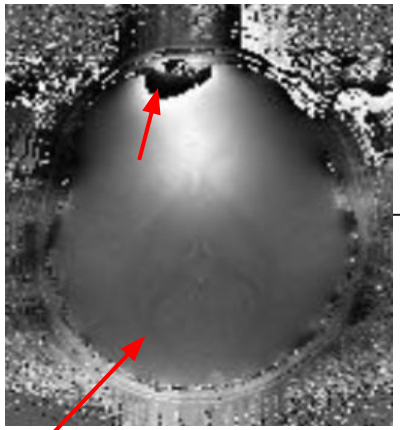


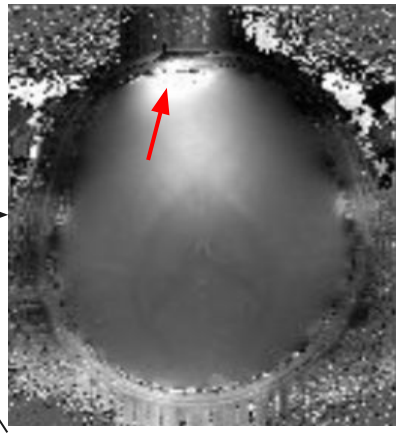


Phase

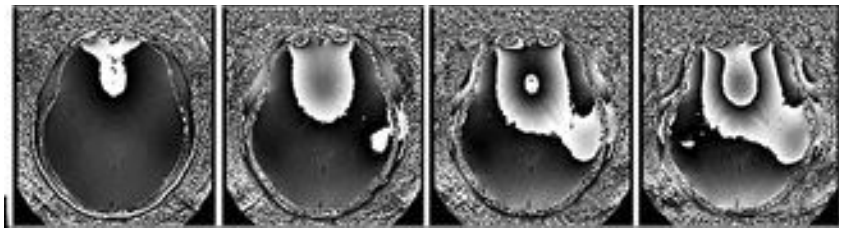
Harada et al., *RadioGraphics*. 2022

Total Field Phase Image has jumps and needs to be unwrapped



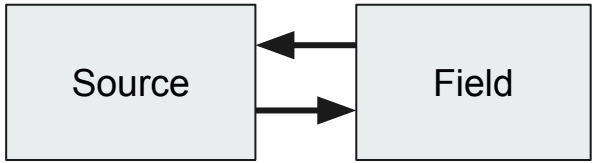


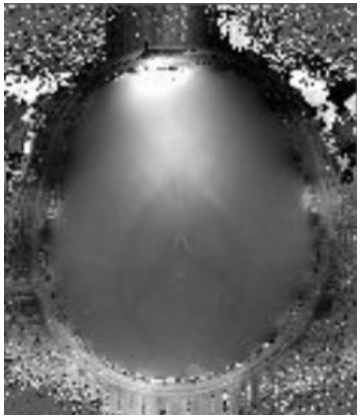
Unwrap Phase Image
(The estimation was periodic ⇒ [-π,π))



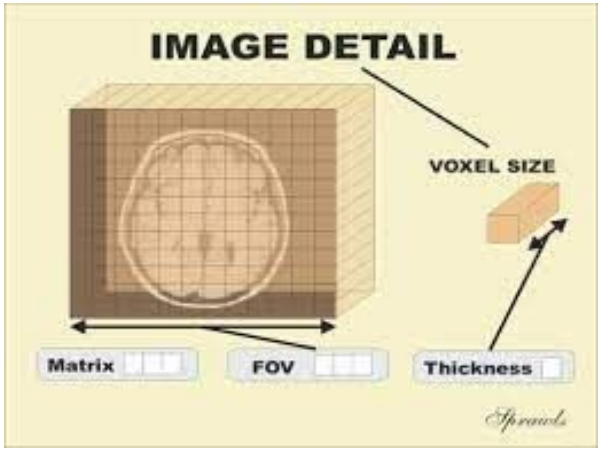
We have total field, but there are challenges for QSM

Challenge #1: Excessive number of sources

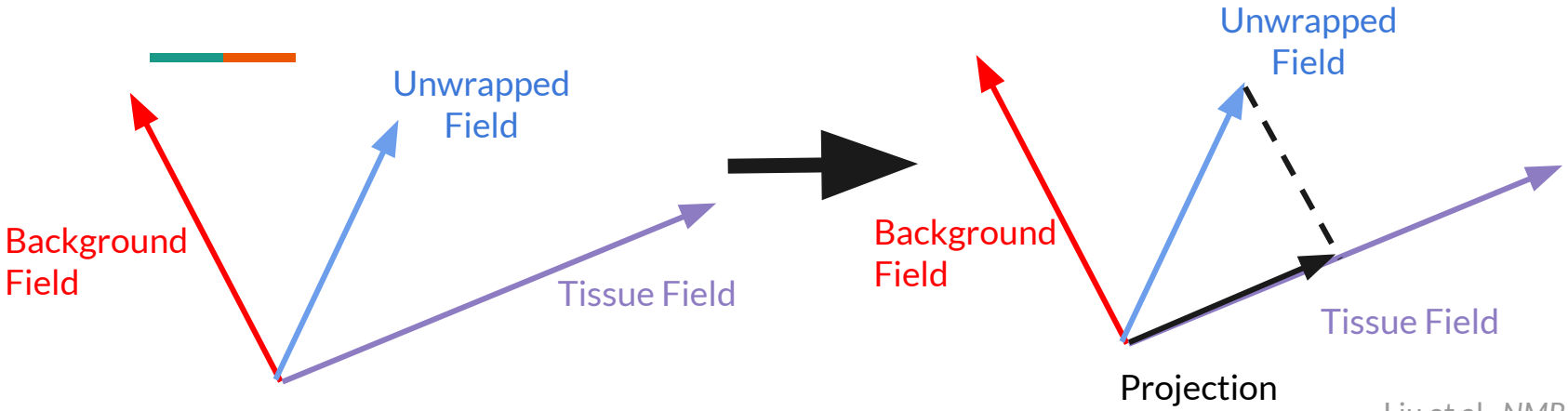




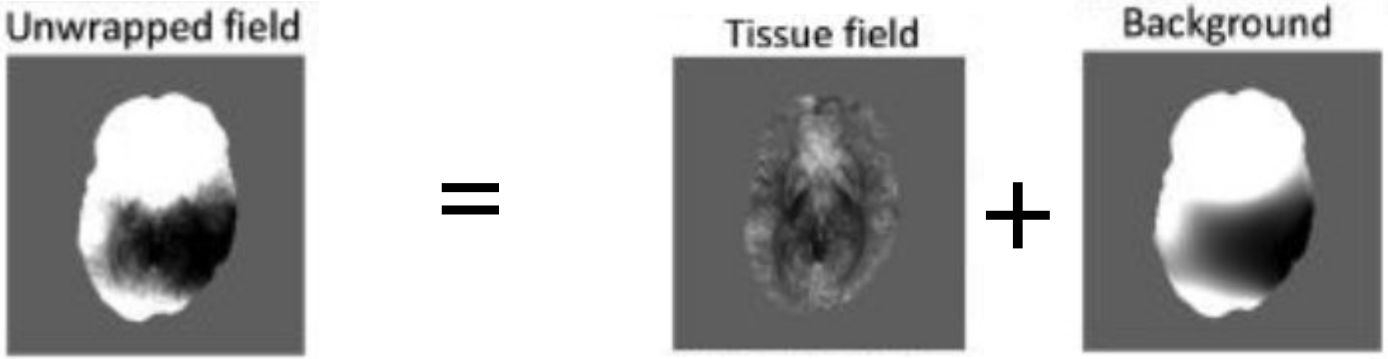
sources > # detectors



Solution #1: Background Field Removal

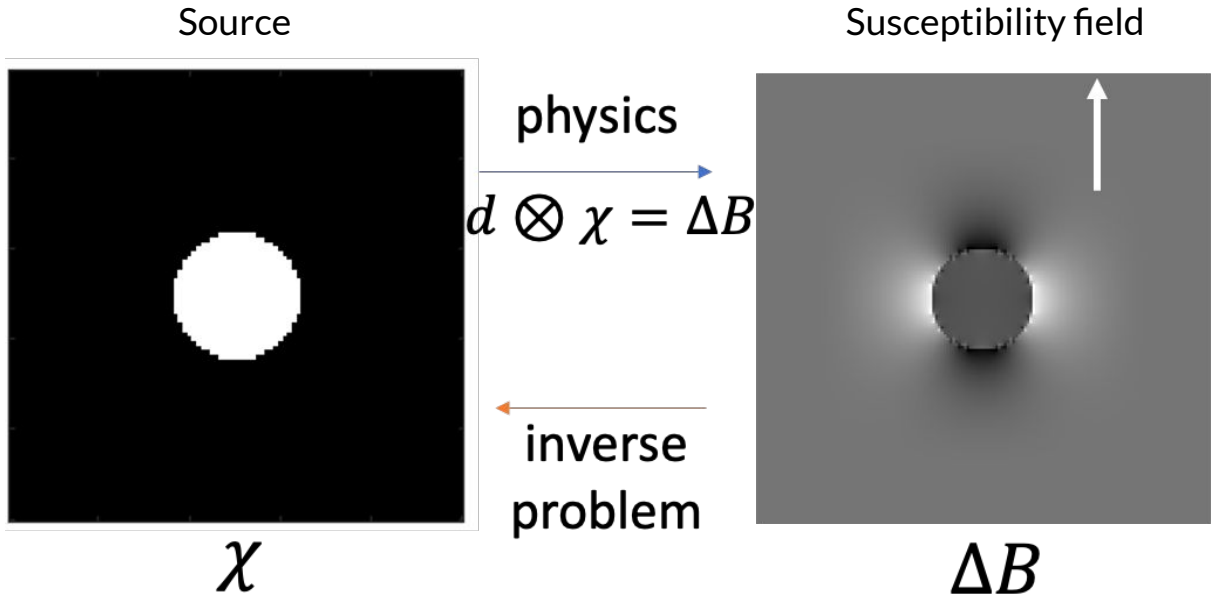


Liu et al., *NMR Biomed*. 2011

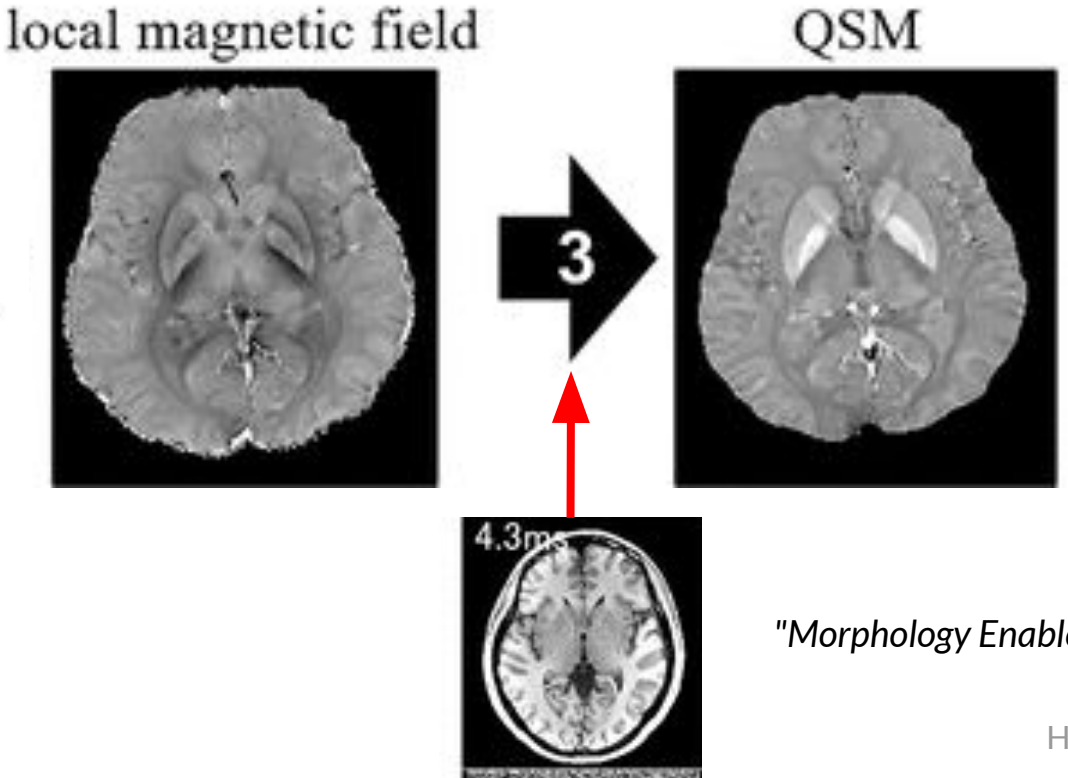


We now have tissue field, but still have another challenge

Challenge #2: Field-to-Susceptibility Inversion



Dipole Inversion is needed to get the susceptibility mapping

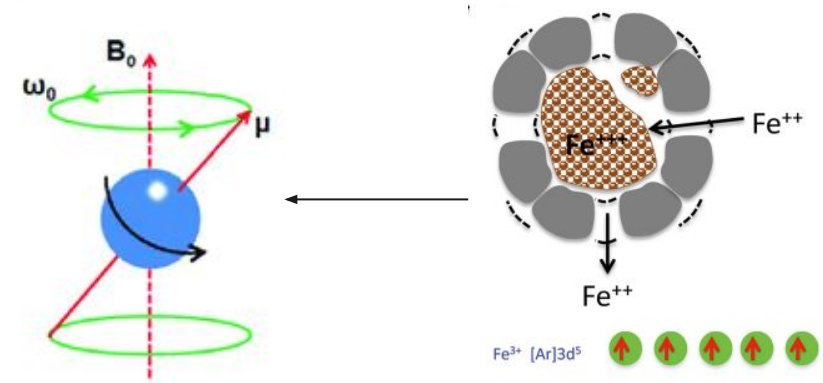


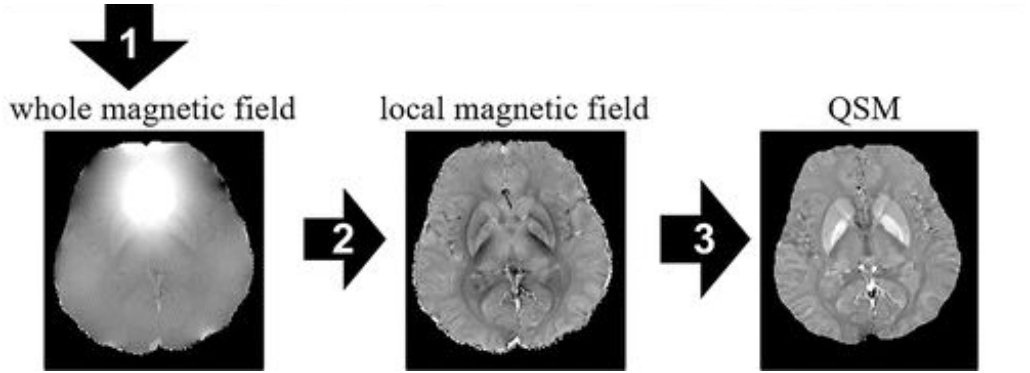
"Morphology Enabled Dipole Inversion"

Harada et al., *RadioGraphics*. 2022

Summary for QSM section

- Ferritin stores iron
- External magnetic field changes how the water spin
- QSM measures susceptibility through MRI signal phase
- QSM overcome challenges
  - Background Field Removal
  - Dipole Inversion





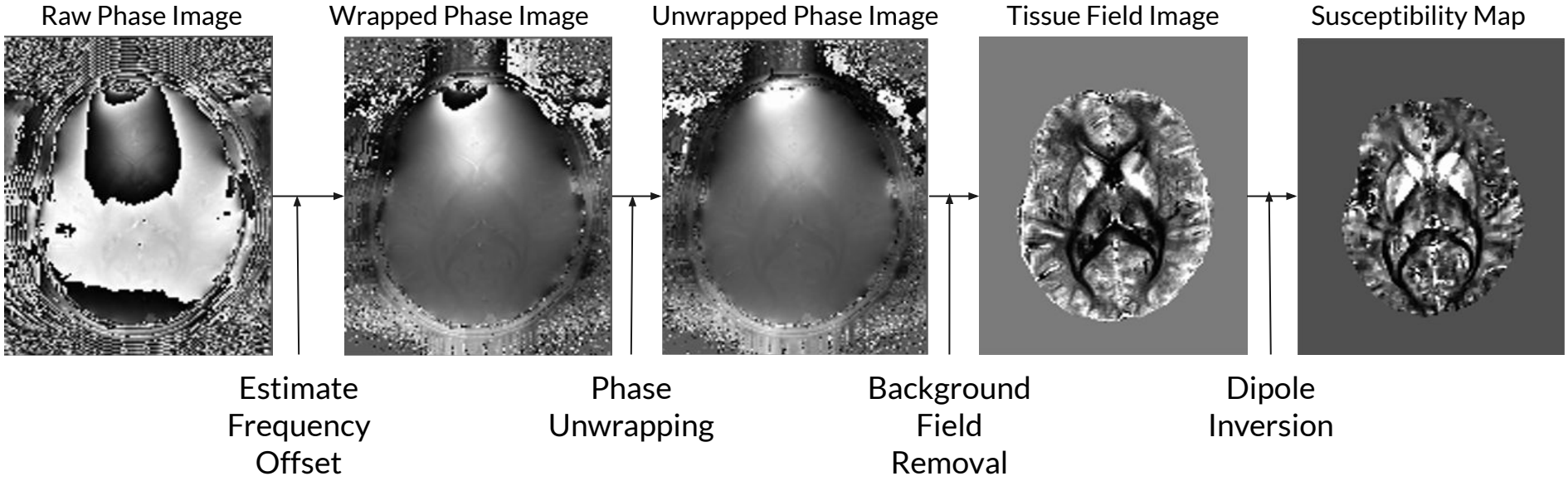
Harada et al., *RadioGraphics*. 2022

Outline

- Why study iron in the brain
- How can QSM help us with studying iron in the brain
- Current workflow ⇒ Custom end-to-end pipeline

That is great, but what have you done so far though?

Pipeline


Raw Phase Image
Wrapped Phase Image
Unwrapped Phase Image
Tissue Field Image
Susceptibility Map
Estimate Frequency Offset
Phase Unwrapping
Background Field Removal
Dipole Inversion

Dataset

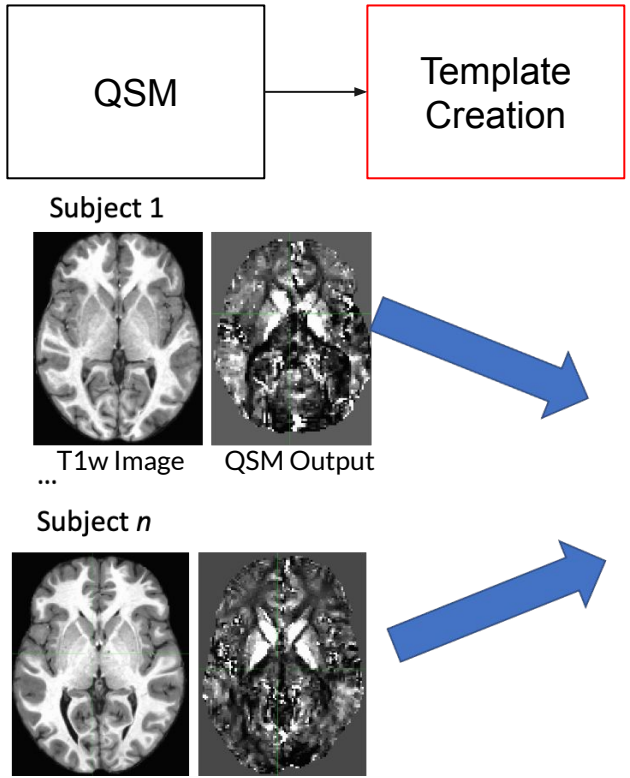
EF

- ~175 subjects
- 3 timepoints
- Age: 8-19
- Psychosis Spectrum
- ADHD
- Typically Developing

MOTIVE

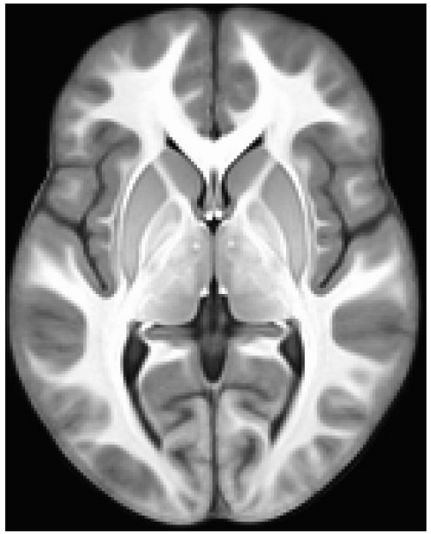
- ~154 subjects
- 2 timepoints
- Age: 16-28
- Psychosis Spectrum
- Typically Developing

Pipeline



`antsMultivariateTemplateConstruction2`

T1w Template

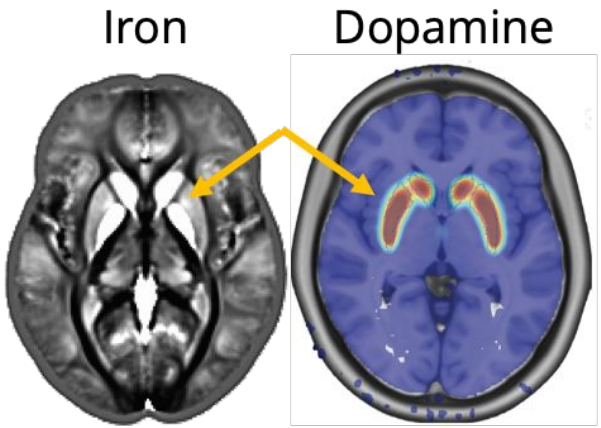


QSM Template

Future Directions

- Differences in QSM level between Psychosis and TD youths
- Reproducible pipeline for other studies

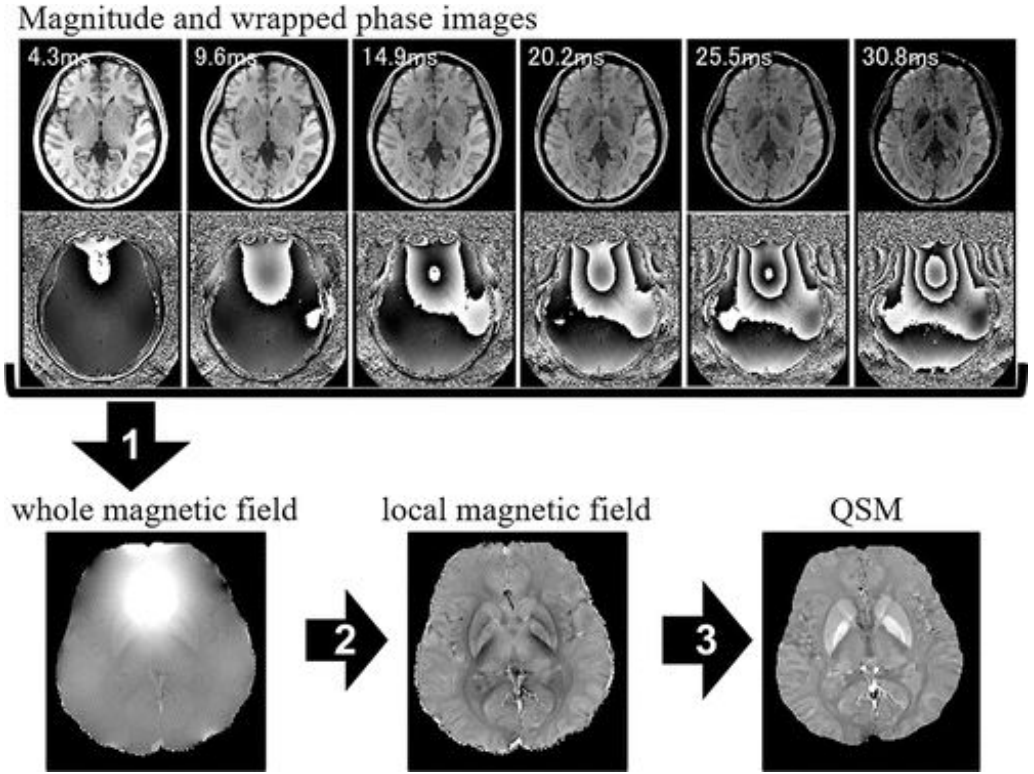
Summary



Larsen & Luna, *Dev. Cogn. Neurosci. 2015*

Larsen et al., *Nature Communications 2020*

Larsen et al., *Journal of Neuroscience 2020*



Harada et al., *RadioGraphics*. 2022

Acknowledgements

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Thank you!!