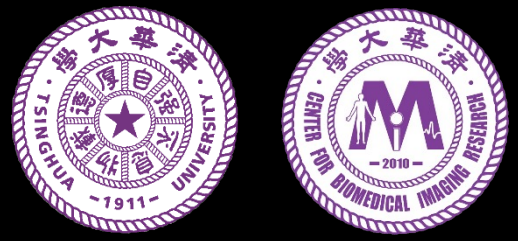

Center for Biomedical Imaging Research

School of Biomedical Engineering Tsinghua University

Slice-POCS-ICE: a navigator-free reconstruction for simultaneous-multislice-accelerated multishot spiral-based diffusion-weighted imaging

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Declaration of Financial Interests or Relationships

Speaker Name: Yuancheng Jiang

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

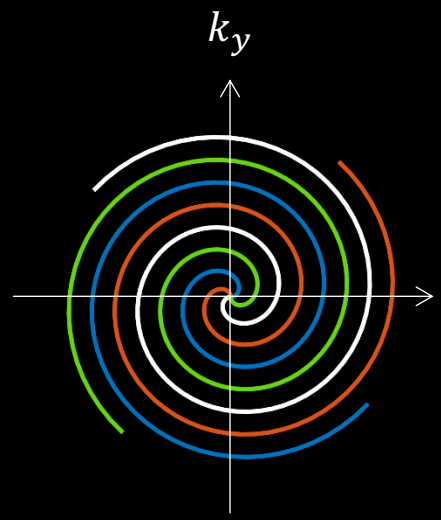
Spiral for DWI

Navigator-free multishot spiral (ms-spiral) is used for DWI acquisition.[1][2]

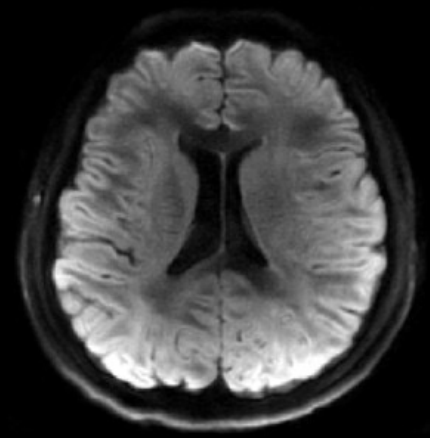
It employs specialized reconstruction methods (e.g. POCS-ICE[3], SENSE+CG[4]) to resolve inter-shot phase variations.

Its sampling efficiency is not optimal.

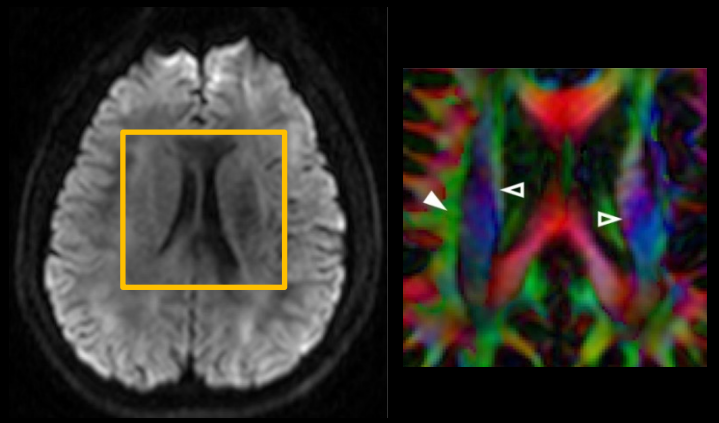
Simultaneous-multislice (SMS) can be used for acceleration.



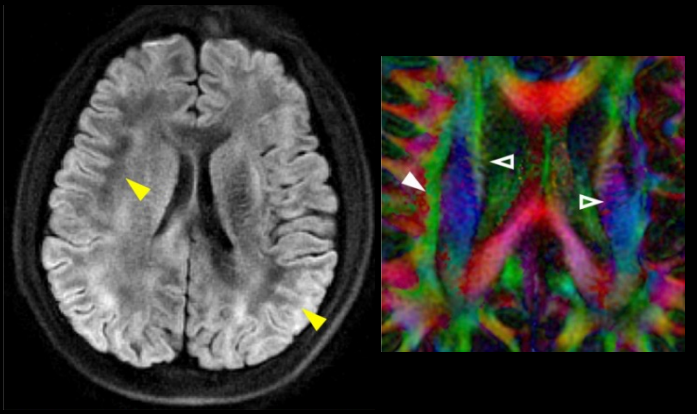
N_{shot} = 4, NSA = 1
TE = 50 ms
1×1×4 mm^3



single-shot reference



POCS-ICE
N_{shot} = 10, N_{coil} = 8



POCS-ICE: POCS-enhanced inherent correction of motion-induced phase errors. SENSE+CG: SENSE with CG reconstruction

[1] Li et al. MRM 2023. [2] Michael et al. MRM 2024 [3] Guo et al. MRM 2016. [4] Truong et al. MRM 2014.

SMS-spiral for DWI

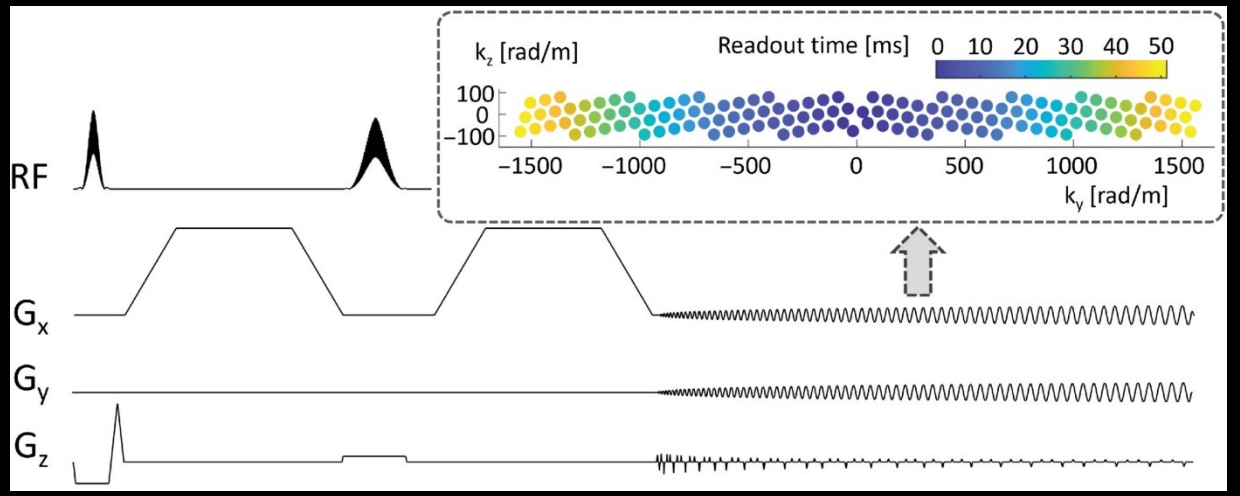
Acquisition

- Usually single-shot spiral for readout.[1]
- Gradient encoding for Controlled Aliasing in Parallel Imaging (CAIPI).[1][2]

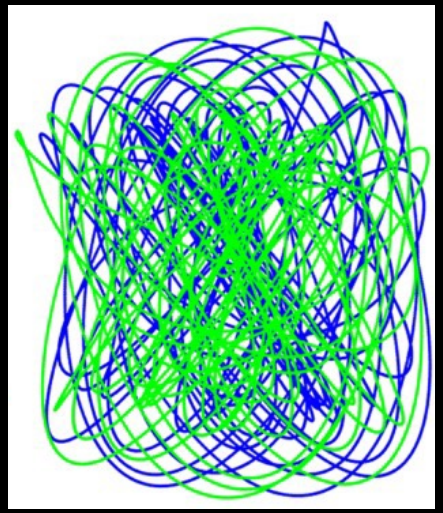
Reconstruction

- Model-based methods.
- 2-step methods.
  - Step 1: resolve slice aliasing (ds-SG[3], NCSG[4]).
  - Step 2: single-band reconstruction.

multiband T-Hex spiral[1]
by applying G_z blips



Wave-spiral[2]
by applying G_z wave



ds-SG: direct-spiral slice-GRAPPA. NCSG: Non-cartesian split-slice-grappa.

[1] Engel et al. MRM 2023. [2] Herbst et al. MRM 2017 [3] Ye et al. MRM 2017. [4] Sun et al. MRM 2020.

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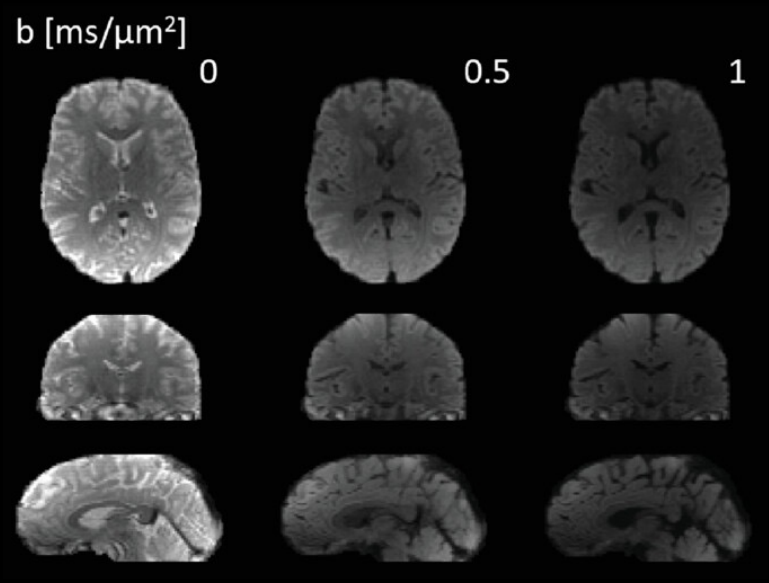
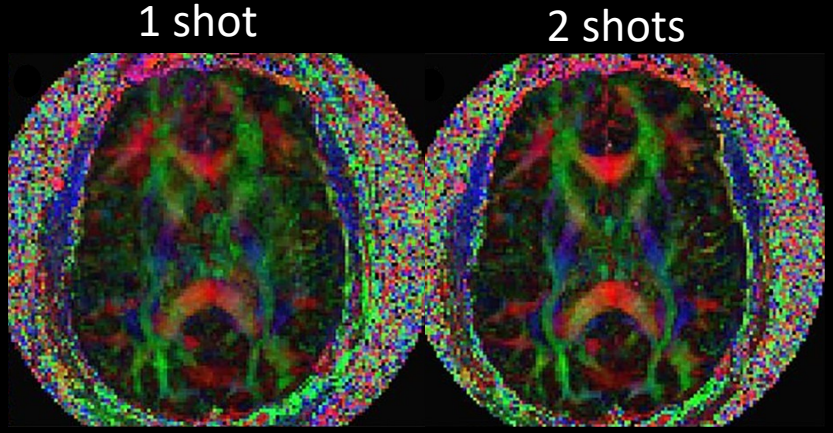
mean DWI by multiband T-Hex spiral[1]
2 mm isotropic



color-FA maps by wave-spiral[2]
1.5 mm isotropic



[1] Engel et al. MRM 2023. [2] Herbst et al. MRM 2017. [3] Ye et al. MRM 2017. [4] Sun et al. MRM 2020.

SMS-spiral for DWI

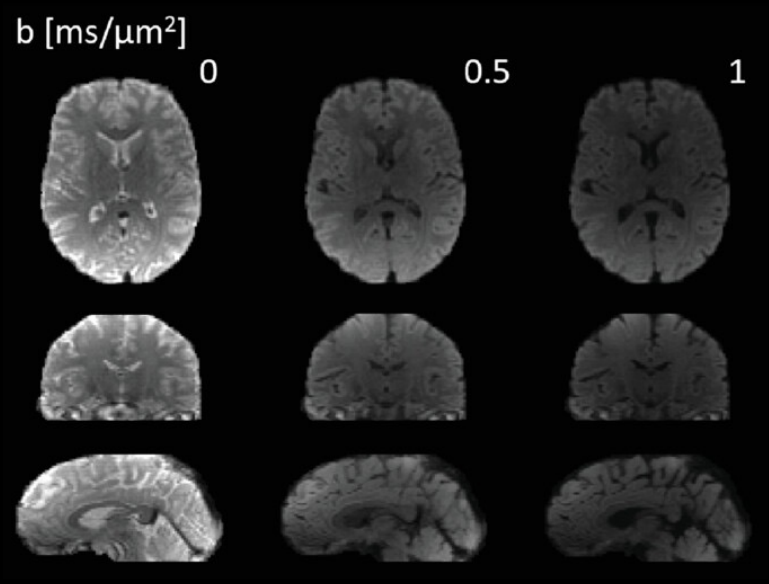
Limitations

- G_z gradients introduced for CAIPI can exacerbate the trajectory error.
- The resolution or image quality is not optimal.
- Current reconstruction methods are not easily applicable to multishot data.

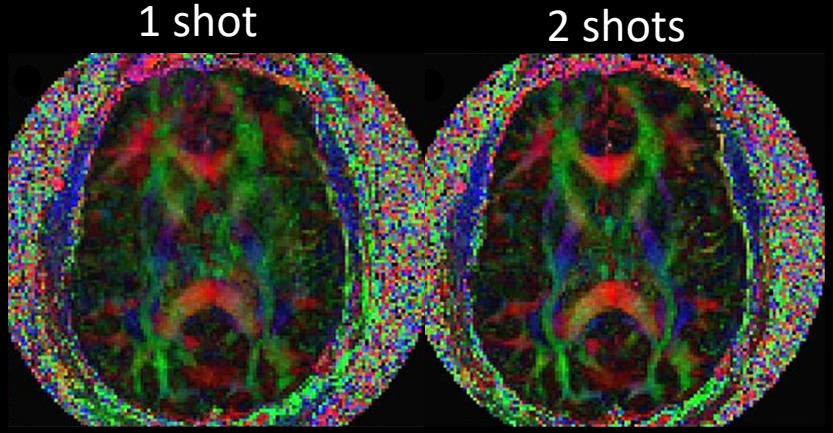
This work

- Employed multishot readout with RF pulse encoding for CAIPI.
- Proposed a new model-based reconstruction algorithm (slice-POCS-ICE).

mean DWI by multiband T-Hex spiral[1]
2 mm isotropic



color-FA maps by wave-spiral[2]
1.5 mm isotropic



slice-POCS-ICE: slice-POCS-enhanced inherent correction of motion-induced phase errors.

[1] Engel et al. MRM 2023. [2] Herbst et al. MRM 2017. [3] Wu et al. ISMRM 2023. [4] Wu et al. ISMRM 2024.

Acquisition

Spiral data for shot i, coil j ($d_{i,j}$):

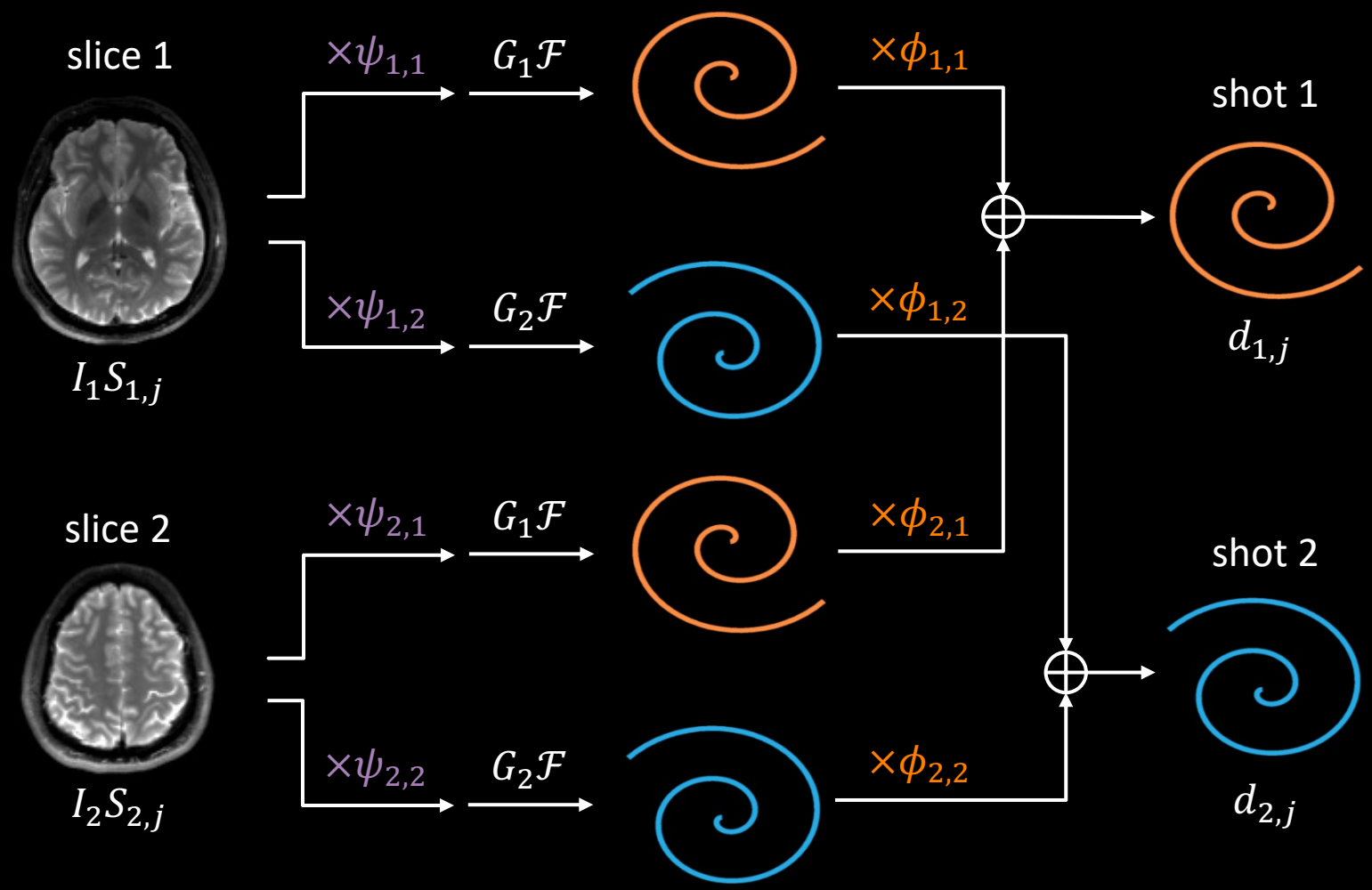
$$d_{i,j} = \sum_{n=1}^{N_{MB}} \phi_{n,i} G_i \mathcal{F} S_{n,j} \psi_{n,i} I_n$$

$$\phi_{n,i} = e^{-\mathrm{j}2\pi(n-1)(i-1)/N_{MB}}$$

$\psi_{n,i}$: inter-shot phase variations for slice n, shot i.

Reconstruction is to estimate:

$\psi_{n,i}$ and I_n



Reconstruction

Slice-POCS-ICE:

- Model-based iterative method.
- Resolve slice aliasing and inter-shot phase variations concurrently.

Input

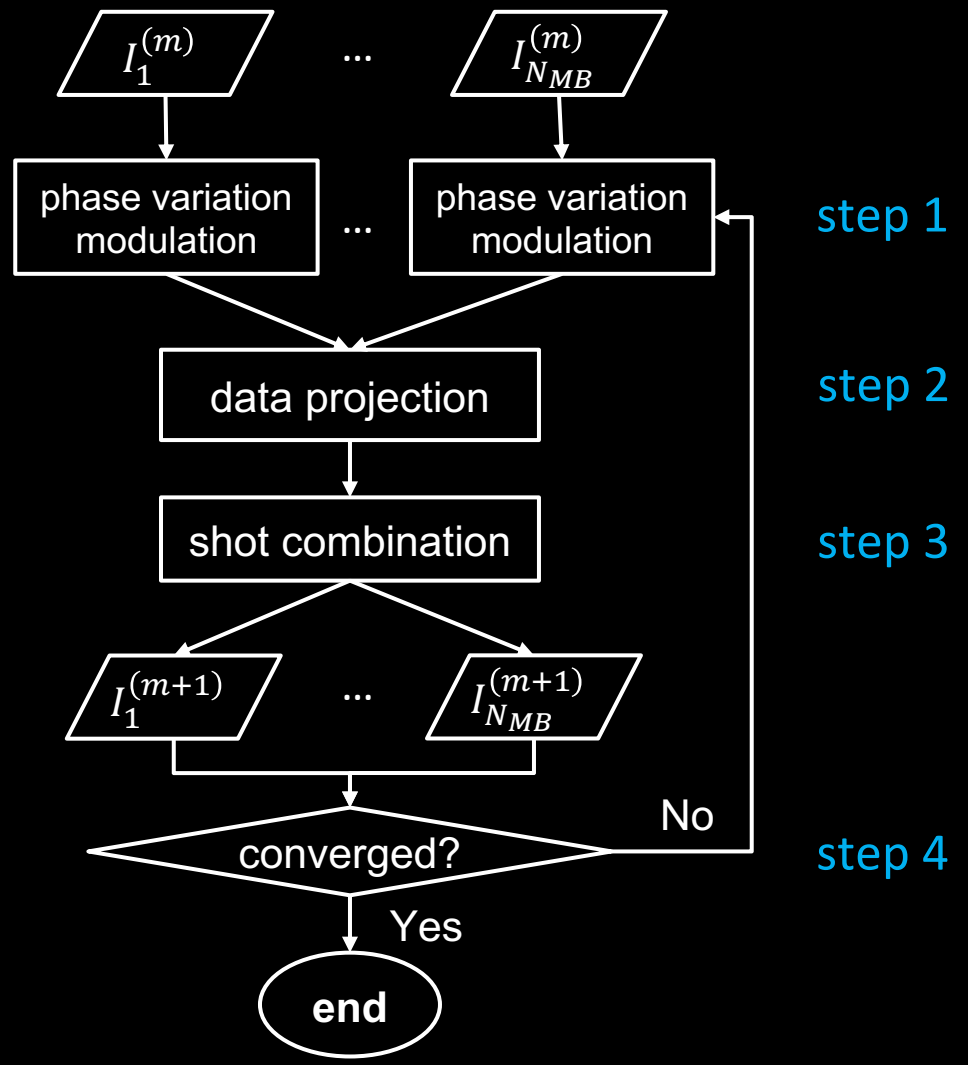
- All the slices that are simultaneously excited by one RF pulse.

Data projection

- Jointly update each slice by POCS.

Output

- Images and phase variations for all the slices.



POCS: Projection onto convex set.

Experiments

Simulation experiments

- Simulation experiments were conducted on a T2 head volume.
- The SMS ms-spiral acquisition procedure was simulated.

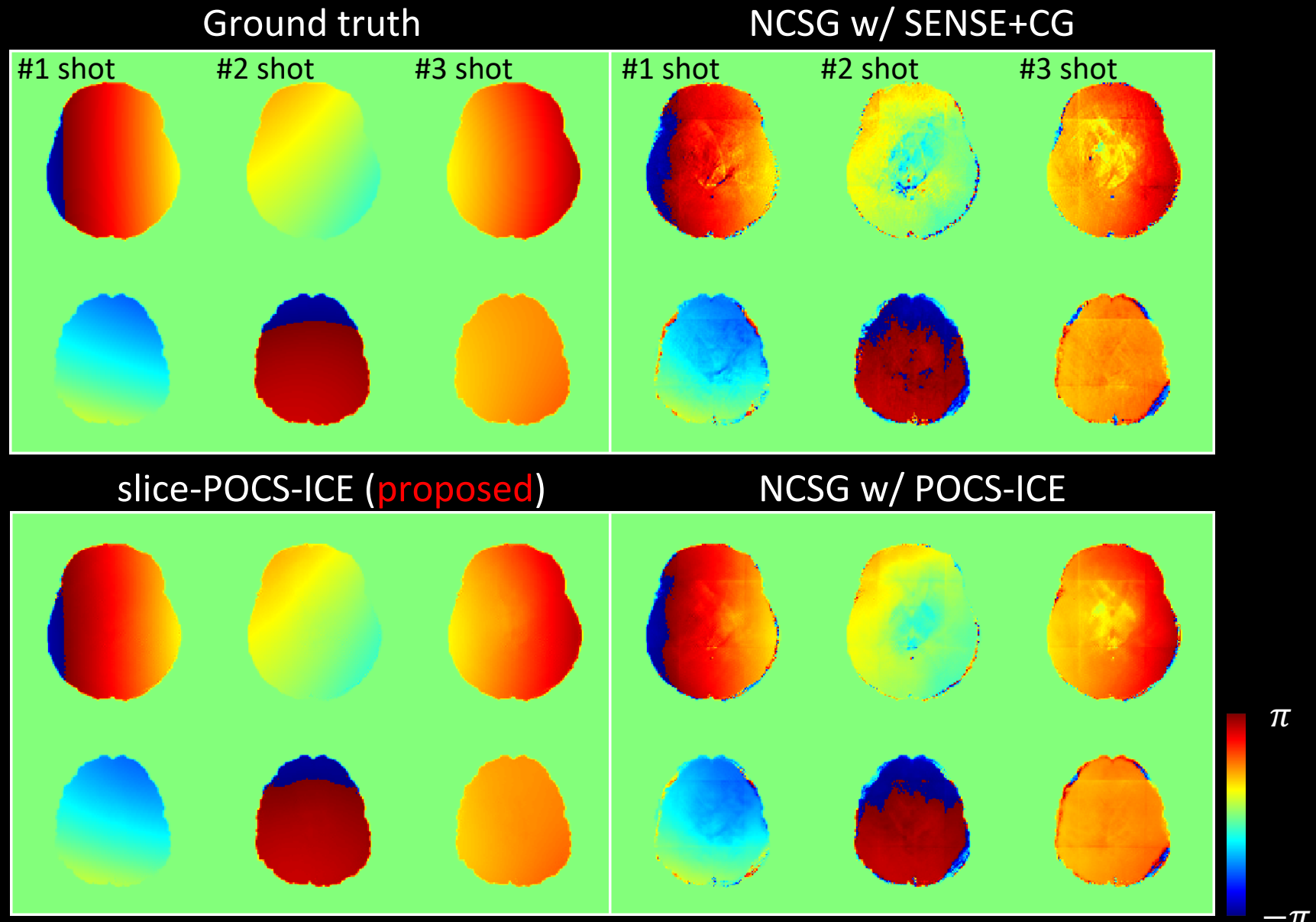
In vivo experiments

- High-resolution diffusion data were acquired by navigator-free SMS ms-spiral sequence.
- Single-band data were acquired as a reference.

- Slice-POCS-ICE was compared to the 2-step methods (NCSG w/ POCS-ICE and NCSG w/ SENSE+CG).

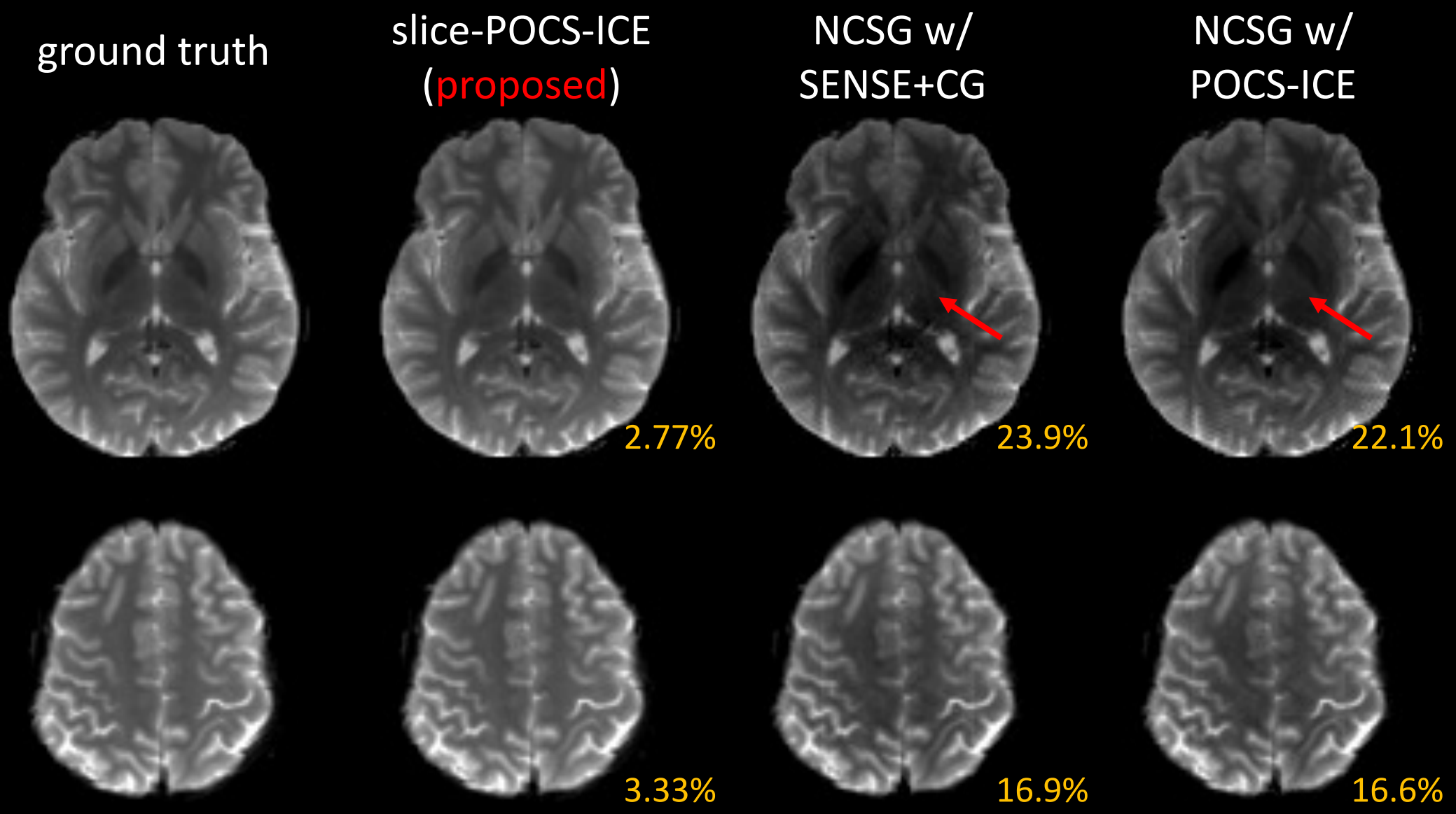
Simulation: phase variation reconstruction

$N_{shot} = 3$, $N_{MB} = 2$



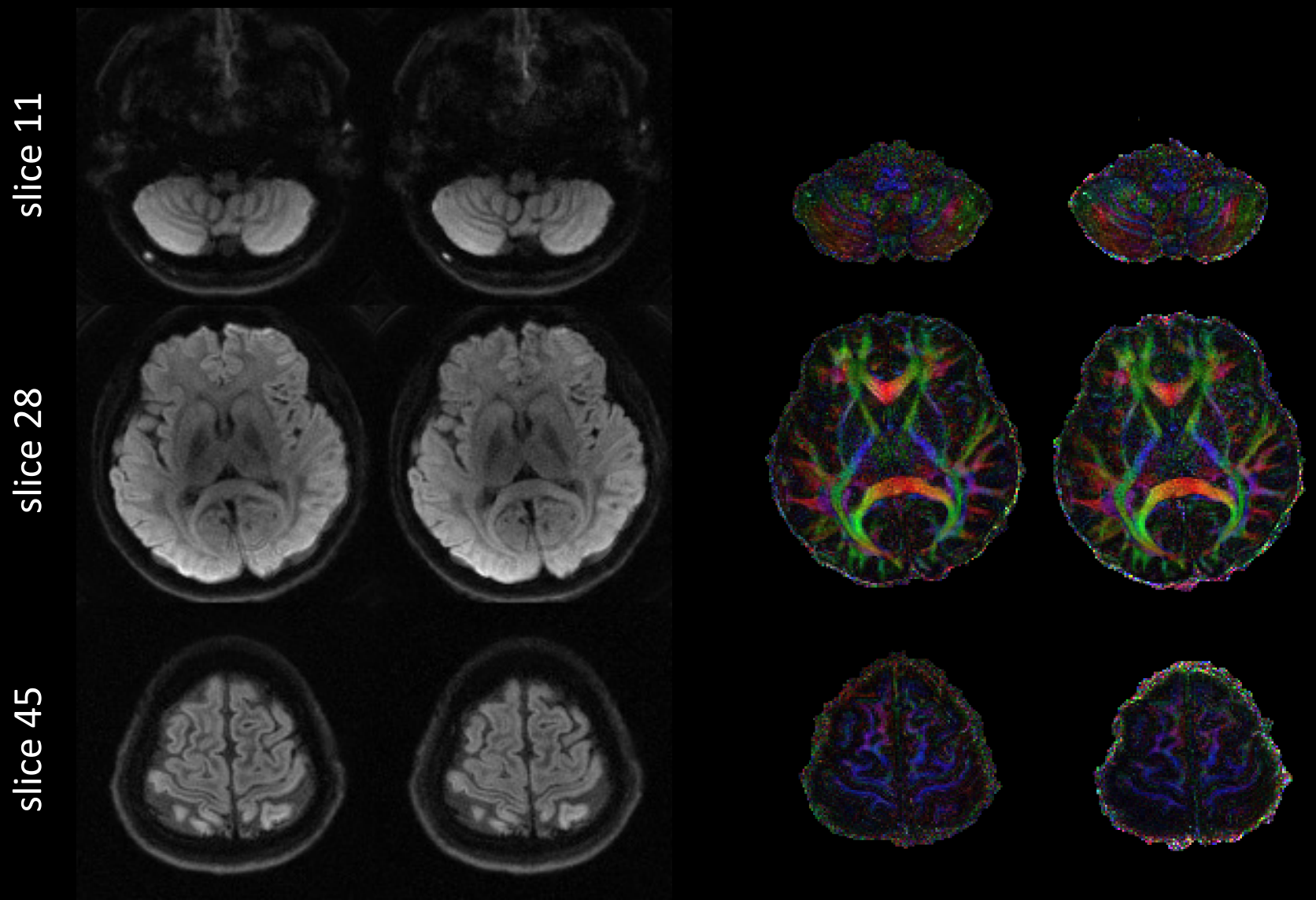
Simulation: image reconstruction

N_{shot} = 3, N_{MB} = 2



In vivo: single-band vs. multi-band

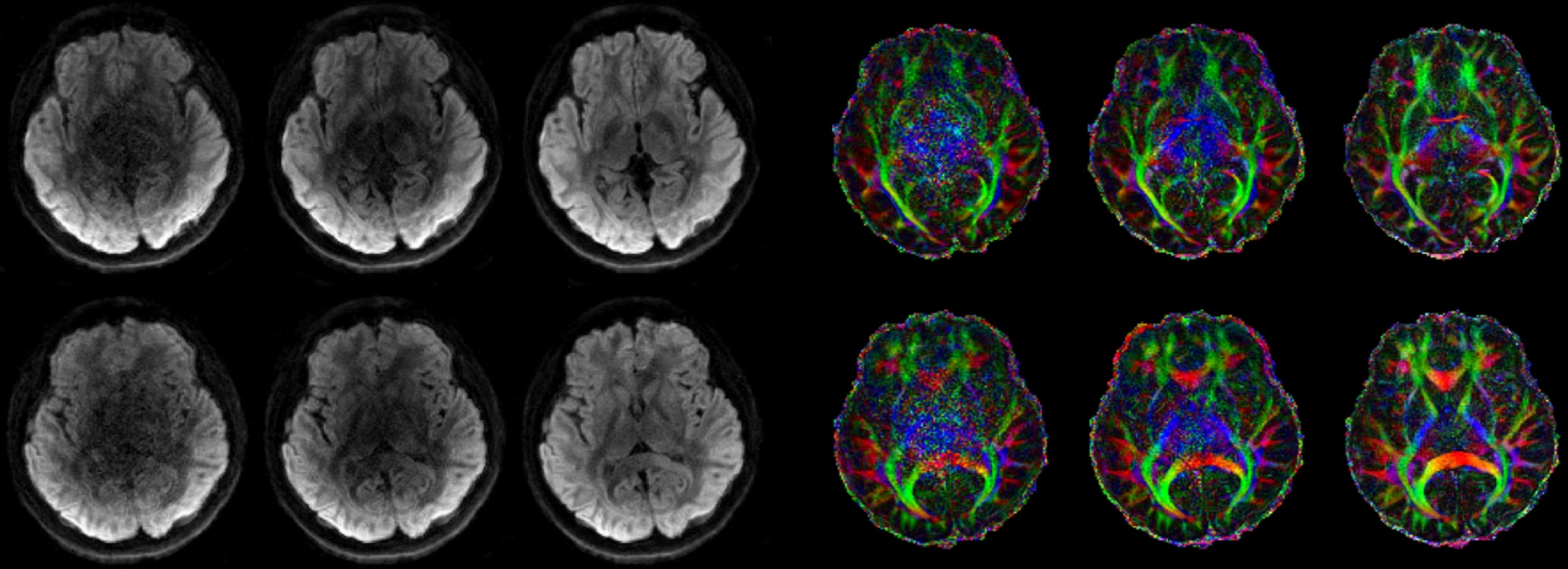
N_{shot} = 4, N_{MB} = 3
1.3×1.3×3.0 mm^3



In vivo: method comparison

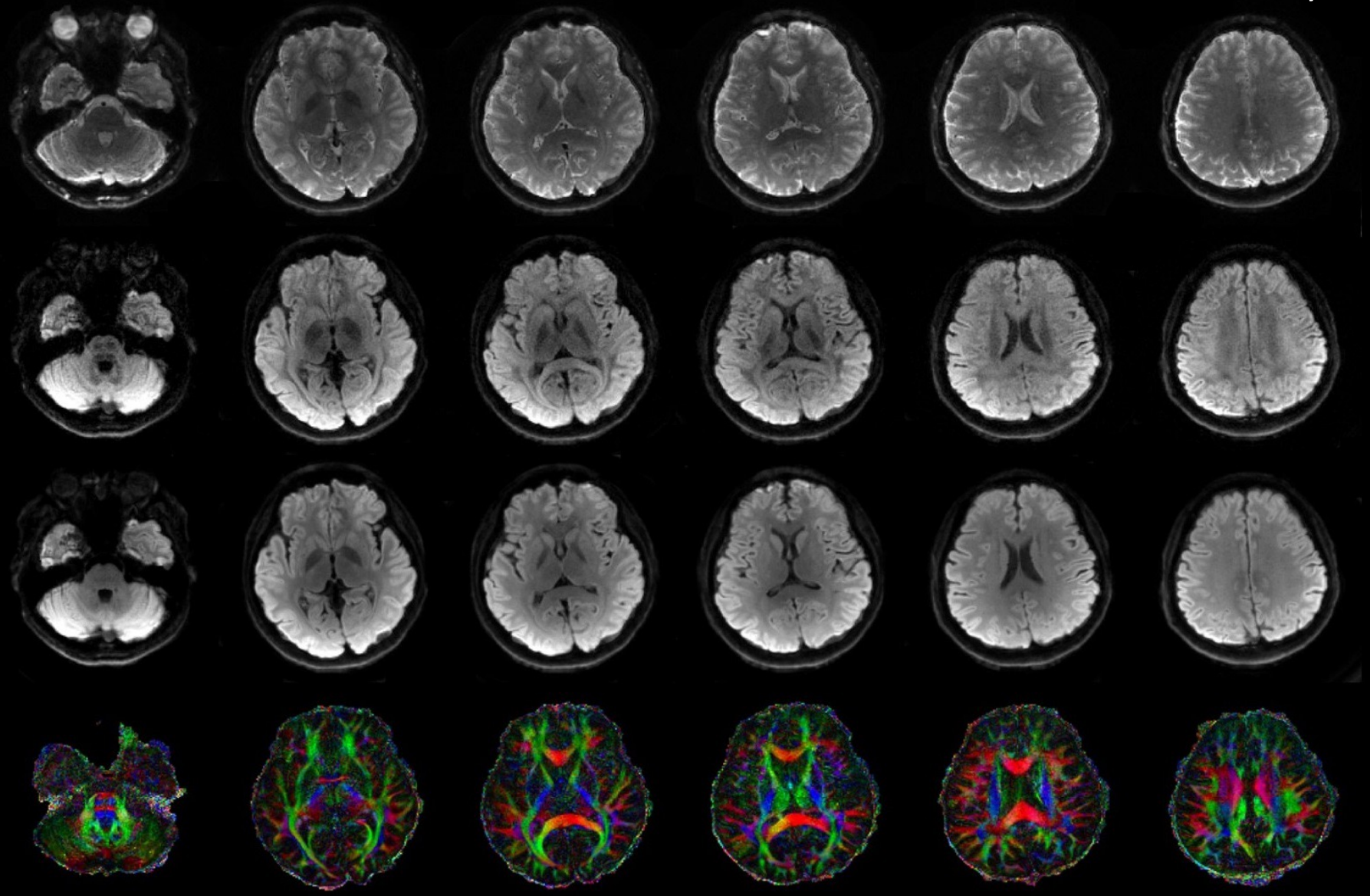
N_{shot} = 4, N_{MB} = 3
1.3×1.3×3.0 mm^3

NCSG w/ SENSE+CG | NCSG w/ POCS-ICE | slice-POCS-ICE (proposed) | NCSG w/ SENSE+CG | NCSG w/ POCS-ICE | slice-POCS-ICE (proposed)



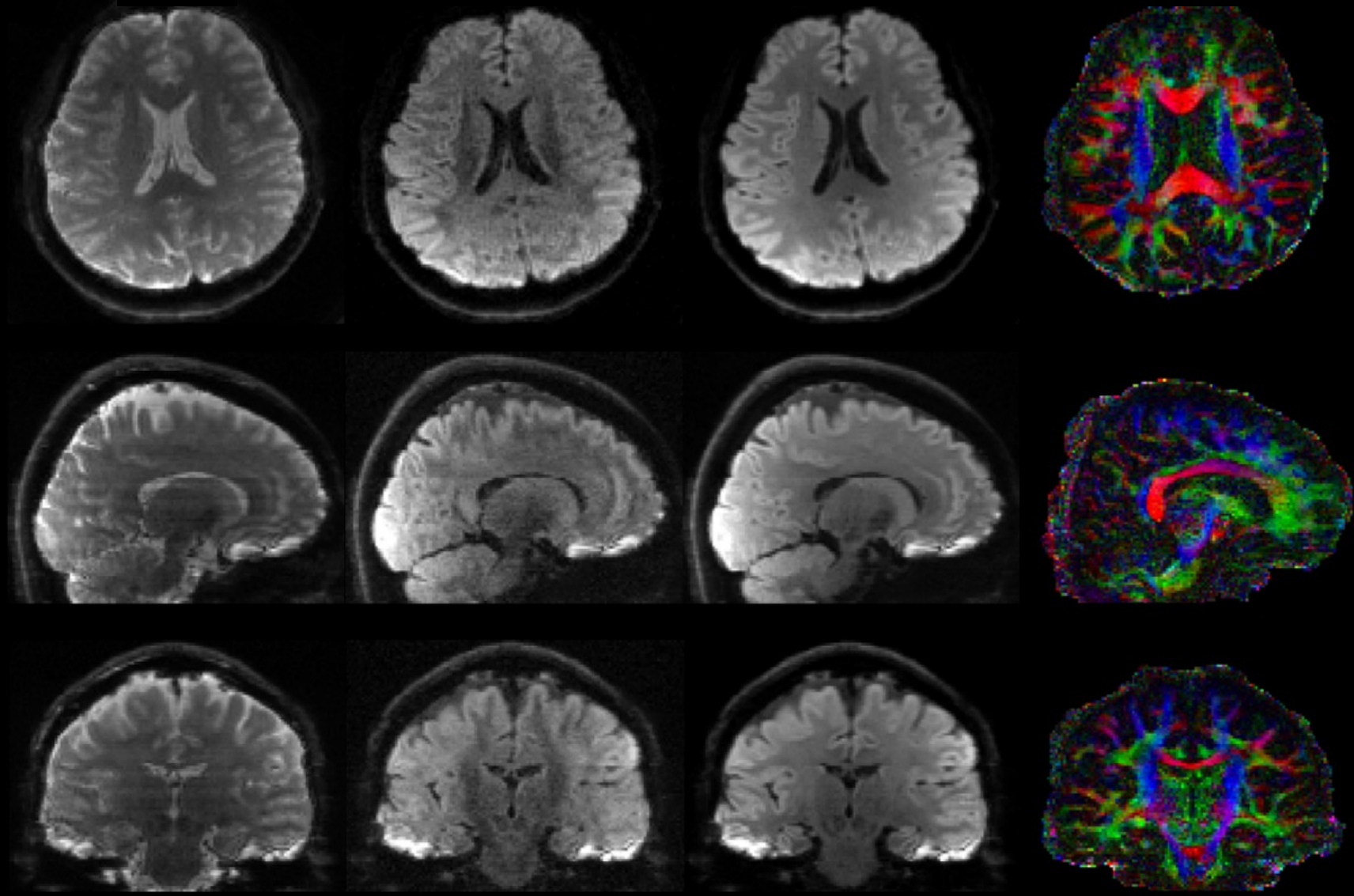
In vivo: image reconstruction

N_{shot} = 4, N_{MB} = 3
1.3×1.3×3.0 mm^3
by slice-POCS-ICE



In vivo: whole brain image

N_{shot} = 3, N_{MB} = 2
NSA = 3
1.5×1.5×1.5 mm^3
by slice-POCS-ICE



Discussion and Conclusion

- In this study, we employed SMS to boost the sampling efficiency of navigator-free multi-shot spiral DWI.
- RF phase encoding was used for CAIPI and a new algorithm, slice-POCS-ICE, was proposed for reconstruction.
- The results of Slice-POCS-ICE are better than those of other 2-step methods and show favorable consistency with the single-band reference.
- We successfully achieve high-resolution high-efficiency spiral-based diffusion imaging.

Thanks for you attention!