



Joint Reconstruction of Phase-Cycled Balanced SSFP with Constrained Parallel Imaging

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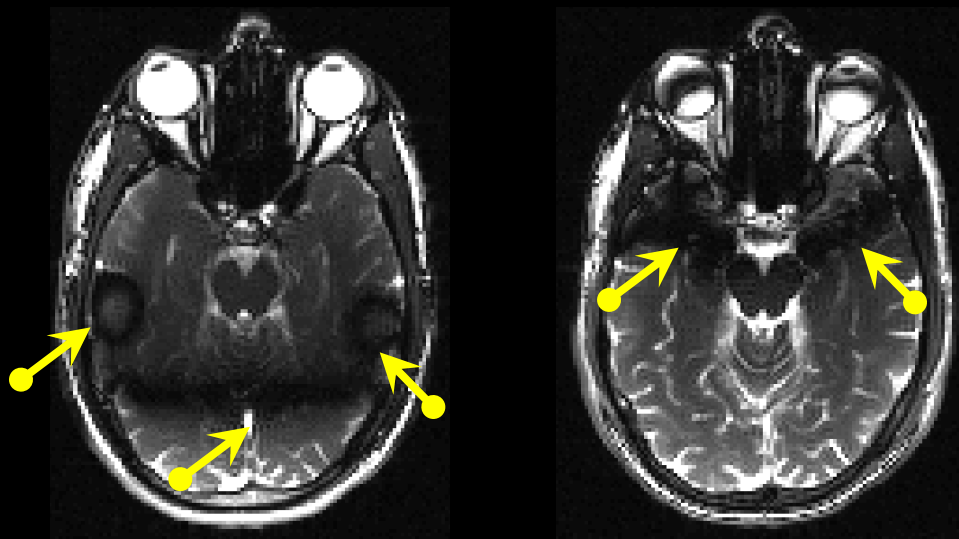
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3 Siemens Medical Solutions, Charlestown, MA, United States

Balanced SSFP

- bSSFP has
 - unique T2 / T1 contrast
 - inherent high SNR efficiency
 - fast imaging time: short TE & TR

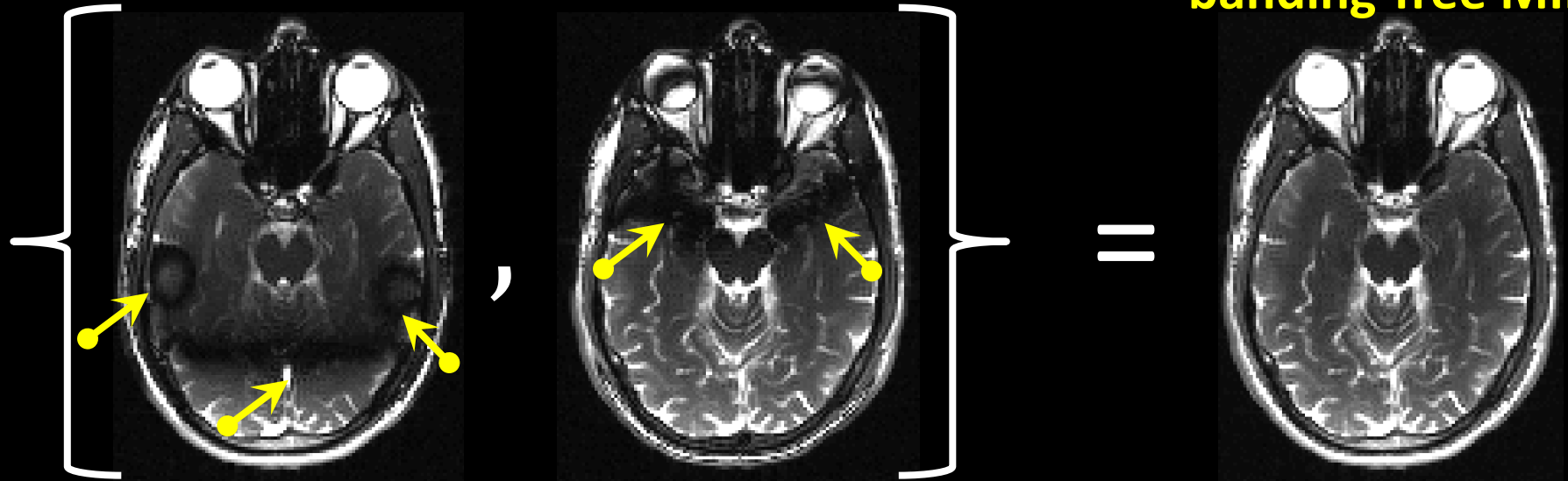
Phase-cycled bSSFP



- But suffers from banding artifacts due to B0 inhomogeneity
- Can be mitigated by phase-cycling:
 - ❖ multiple acquisitions with different phase increment
 - ❖ this shifts location of banding artifacts

Phase-cycled bSSFP

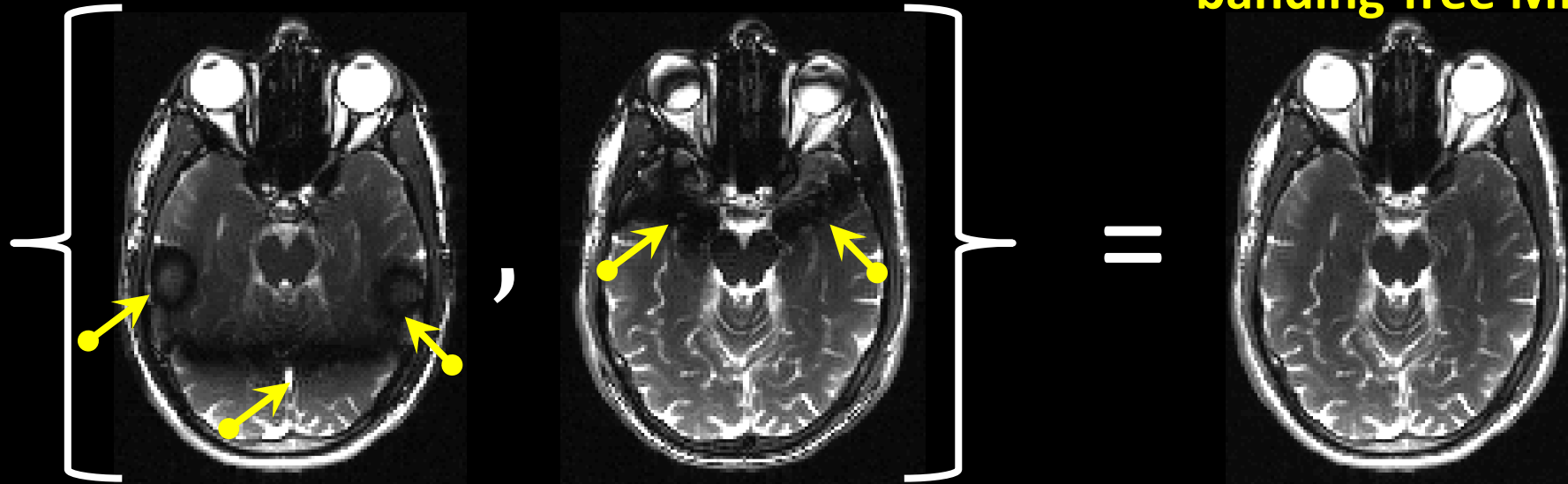
max



- But suffers from banding artifacts due to B0 inhomogeneity
- Can be mitigated by phase-cycling:
 - ❖ multiple acquisitions with different phase increment
 - ❖ this shifts location of banding artifacts
 - ❖ combine cycles with Max Intensity Projection (MIP)

Phase-cycled bSSFP

max



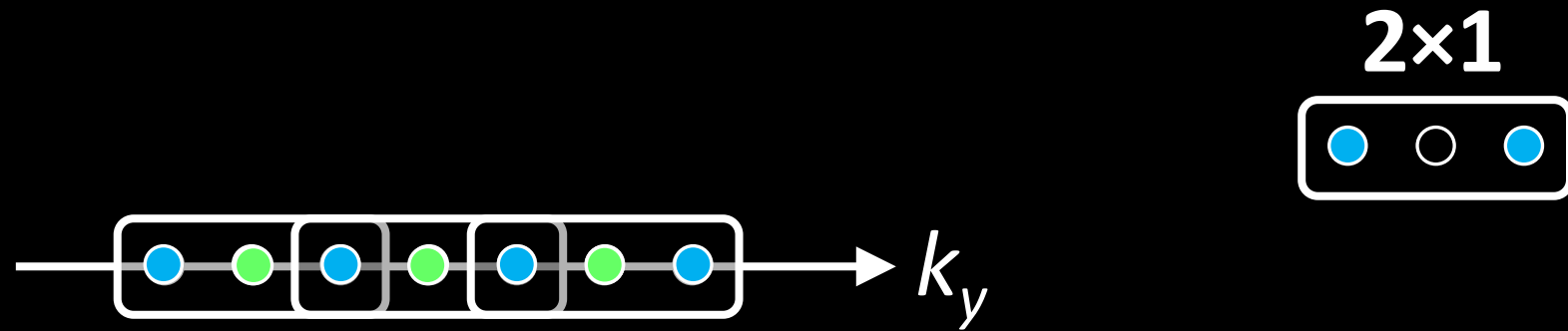
- But suffers from banding artifacts due to B0 inhomogeneity
- Can be mitigated by phase-cycling:
 - ❖ multiple acquisitions increase scan time, counteracting efficiency of bSSFP
 - ❖ Parallel Imaging and Simultaneous MultiSlice (SMS) allowed up to 4-fold acceleration in phase-cycled bSSFP [1,2]

Joint Recon for Phase-cycled bSSFP

- We propose to jointly recon phase-cycled images
- We introduce Joint L1-SPIRiT:
 - ❖ fit SPIRiT kernels [1] jointly across coils and phase-cycles
convert banding artifacts into useful, additional spatial encoding
 - ❖ reduction in g-factor noise amplification is > 1.8 -fold relative to GRAPPA
SNR improvement is similar to 3 averages of GRAPPA recon

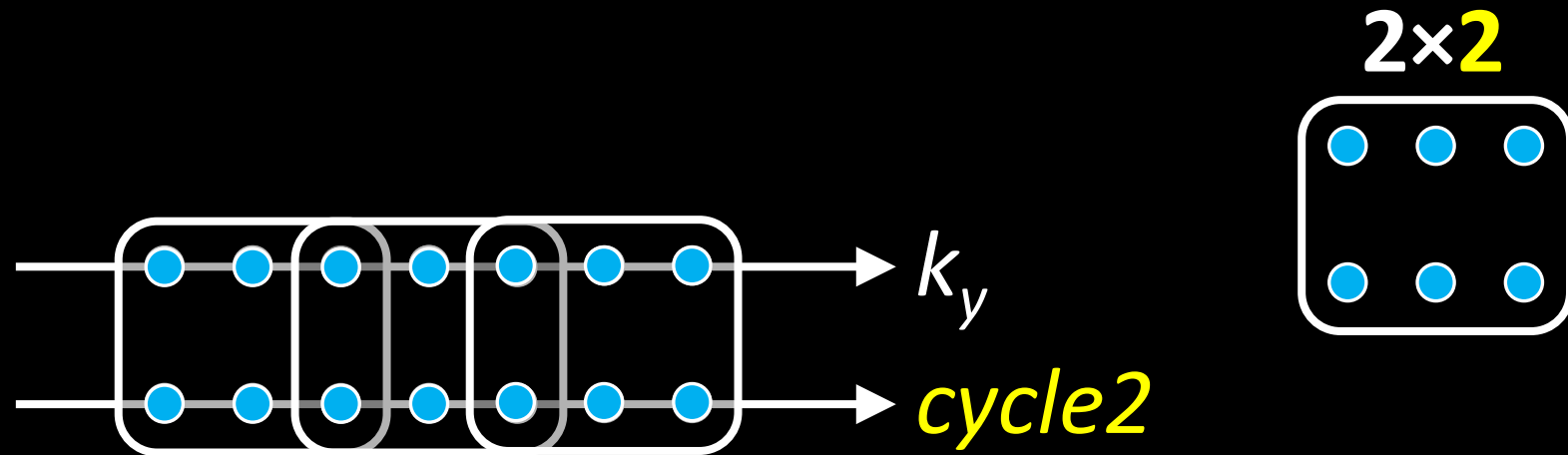
GRAPPA Recon

- R=2 acceleration, ignoring coil and readout axes



Proposed: Joint L1-SPIRiT

- R=2 acceleration, ignoring coil and readout axes



+ Total Variation regularization

Abdominal 2D bSSFP
four phase-cycles, acceleration R=6

Proposed: Joint L1-SPIRiT



GRAPPA



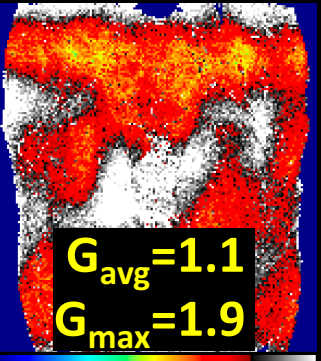
SNR gain:
3 averages of GRAPPA

Error scaled 5x

1/g-factor

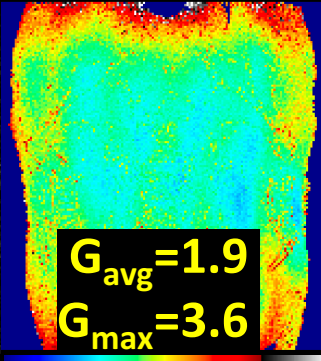
Error scaled 5x

1/g-factor



5.3% RMSE

0% 100% 125%



9.1% RMSE

0% 100% 125%

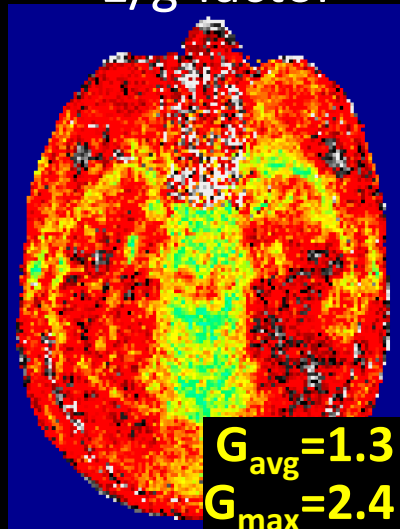
Neuro 2D bSSFP
four phase-cycles, acceleration R=6

Proposed: Joint L1-SPIRiT

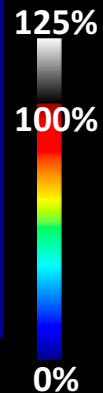


5.2%
RMSE

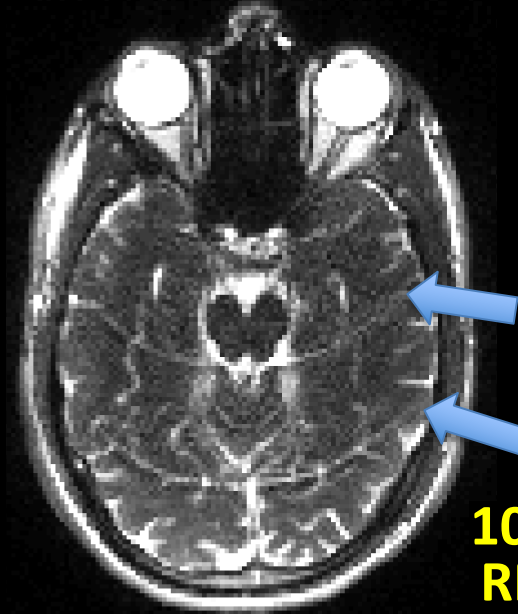
1/g-factor



$G_{avg}=1.3$
 $G_{max}=2.4$

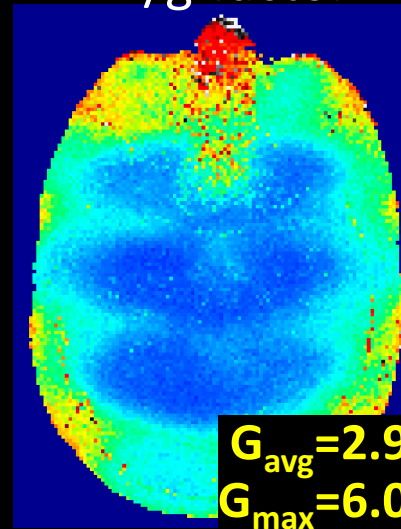


GRAPPA

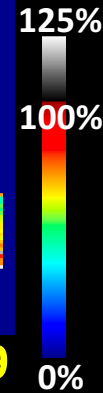


10.0%
RMSE

1/g-factor



$G_{avg}=2.9$
 $G_{max}=6.0$

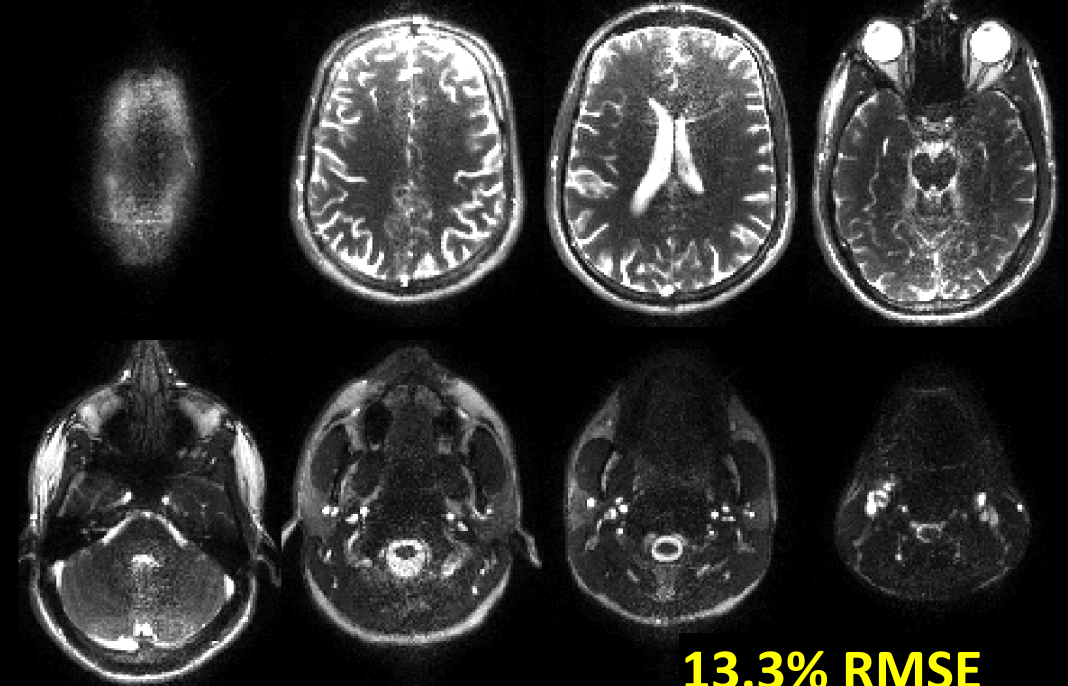
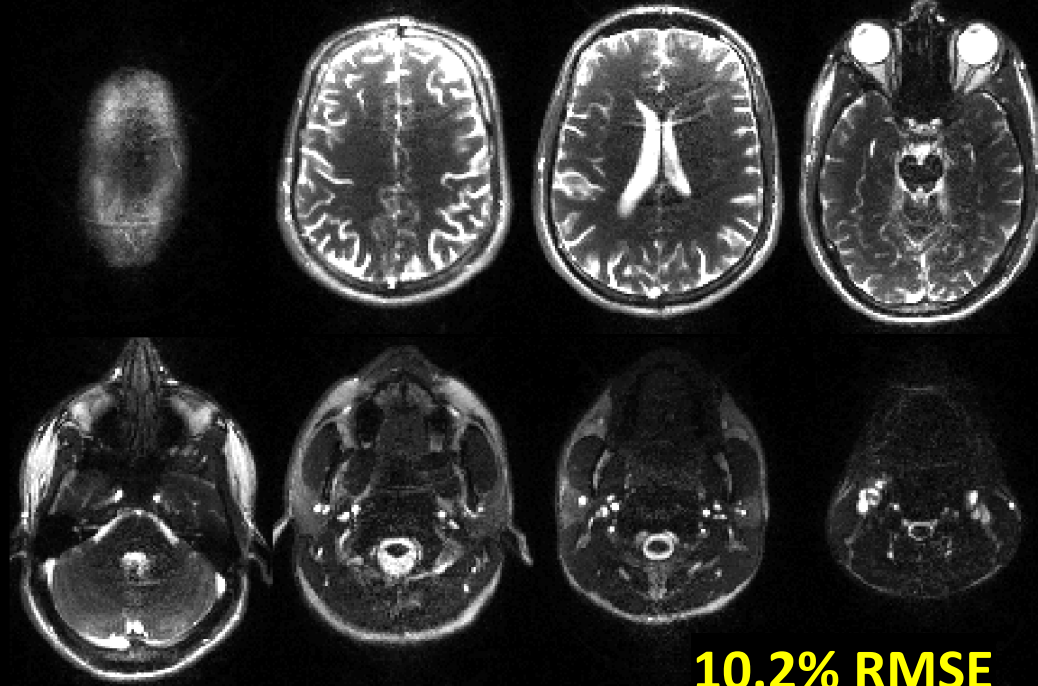


SNR gain:
4 averages of GRAPPA

Neuro SMS bSSFP acquisition
four phase-cycles, MultiBand = 8

Proposed: Joint Slice GRAPPA

Split Slice GRAPPA

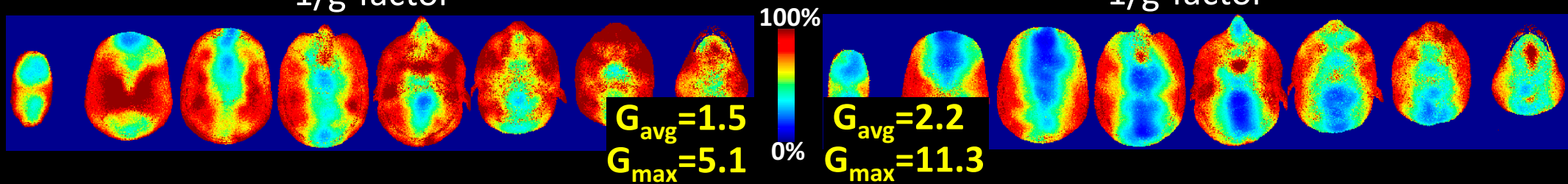


10.2% RMSE

13.3% RMSE

1/g-factor

1/g-factor



SNR gain: 2 averages of Slice GRAPPA