Future Directions in CSF Velocity Imaging

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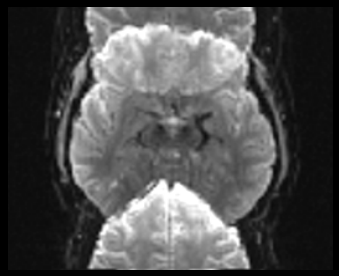
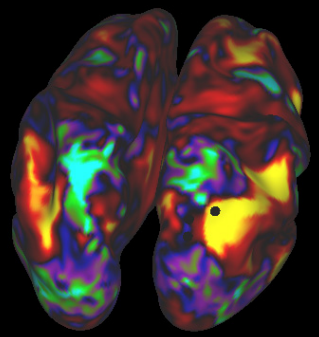
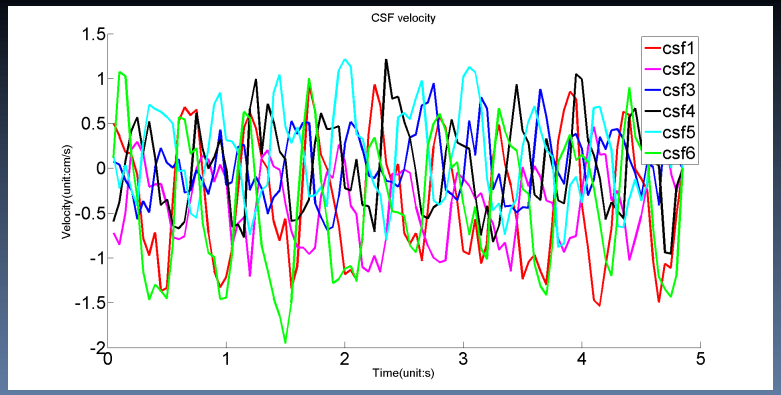
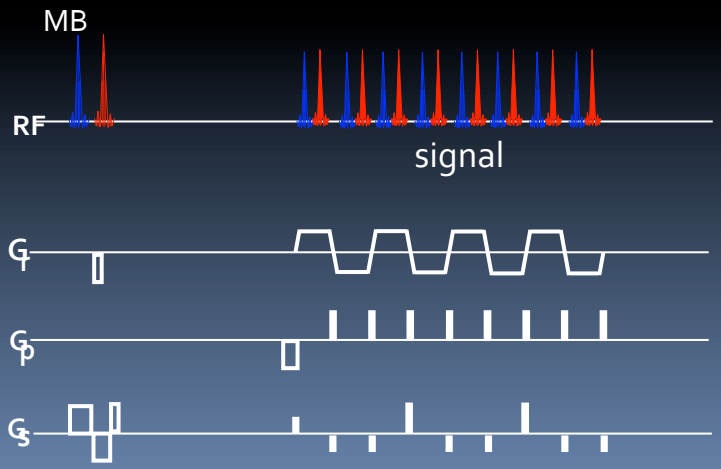
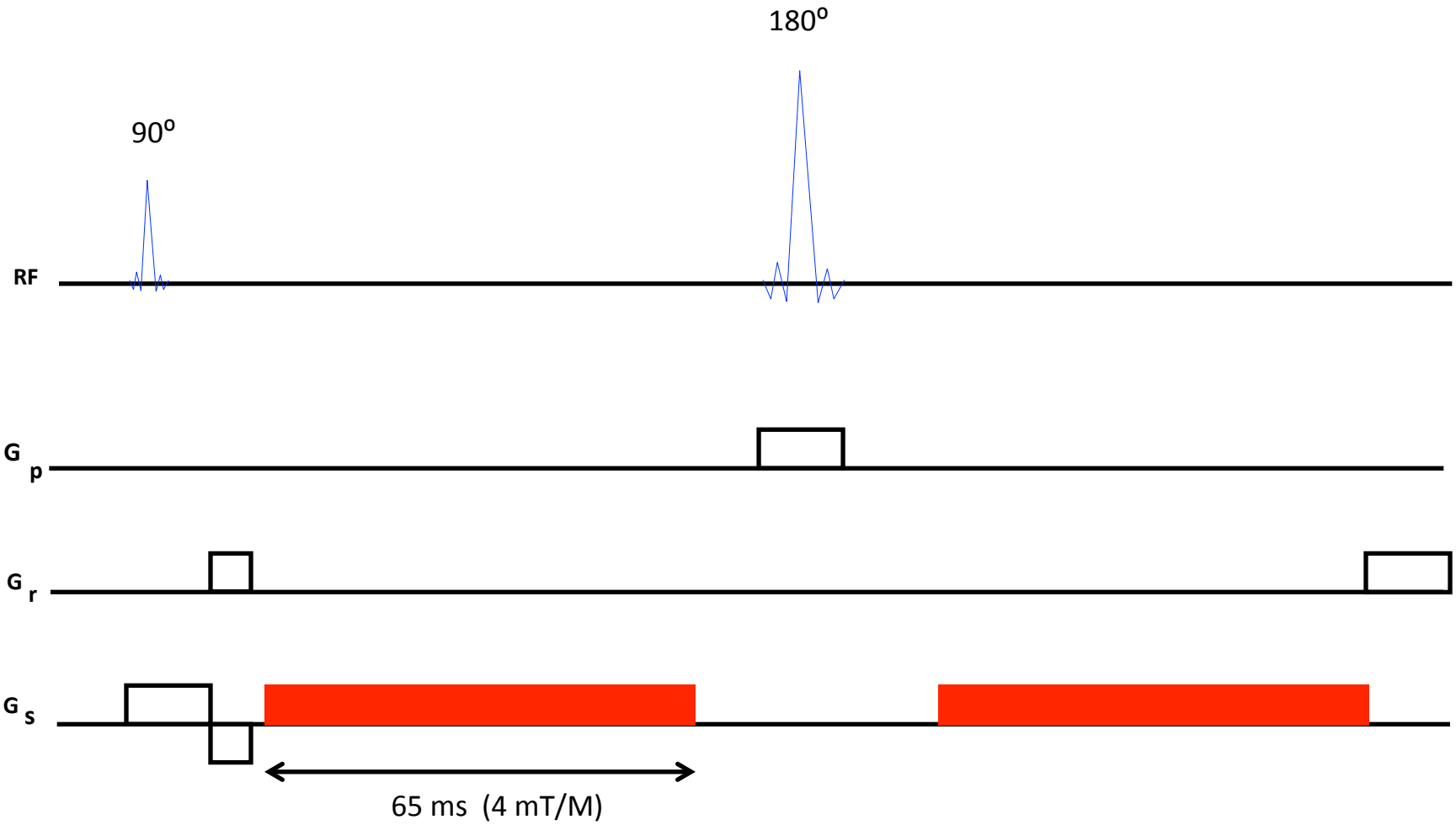




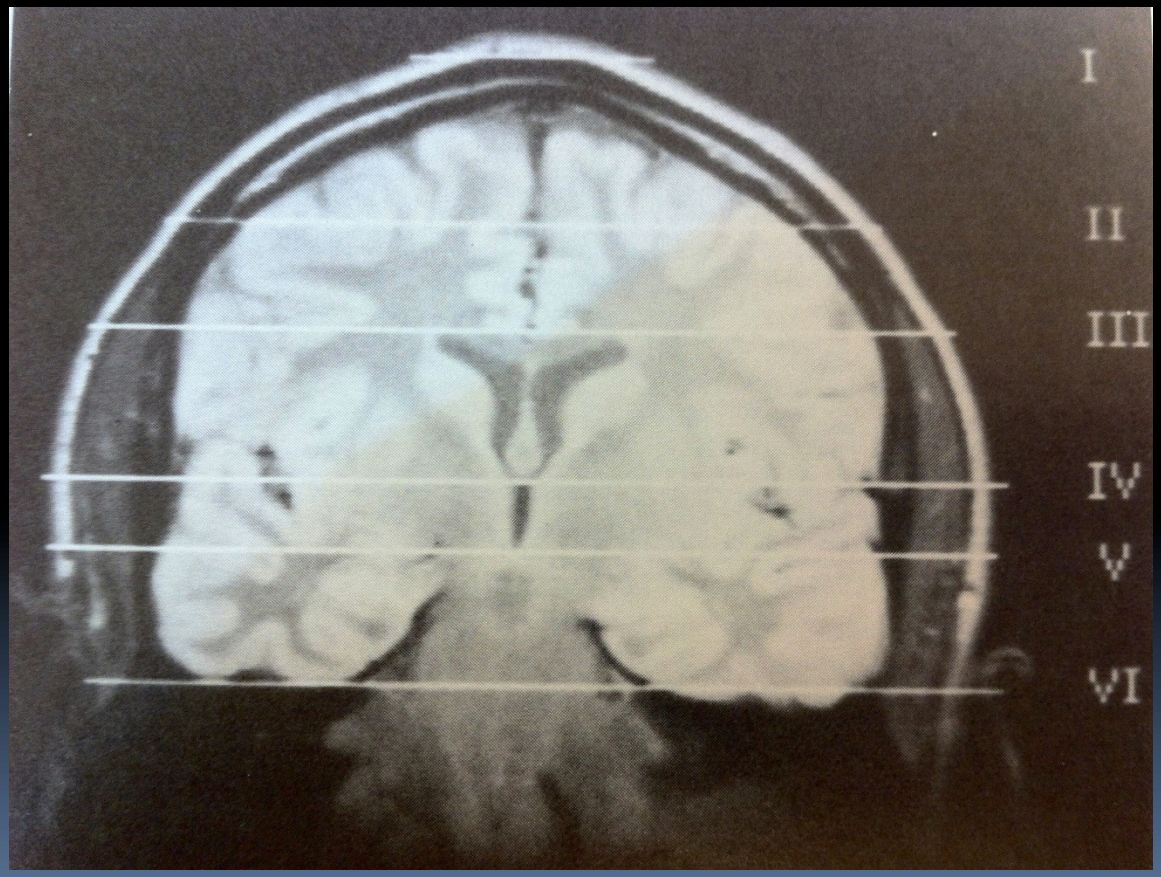




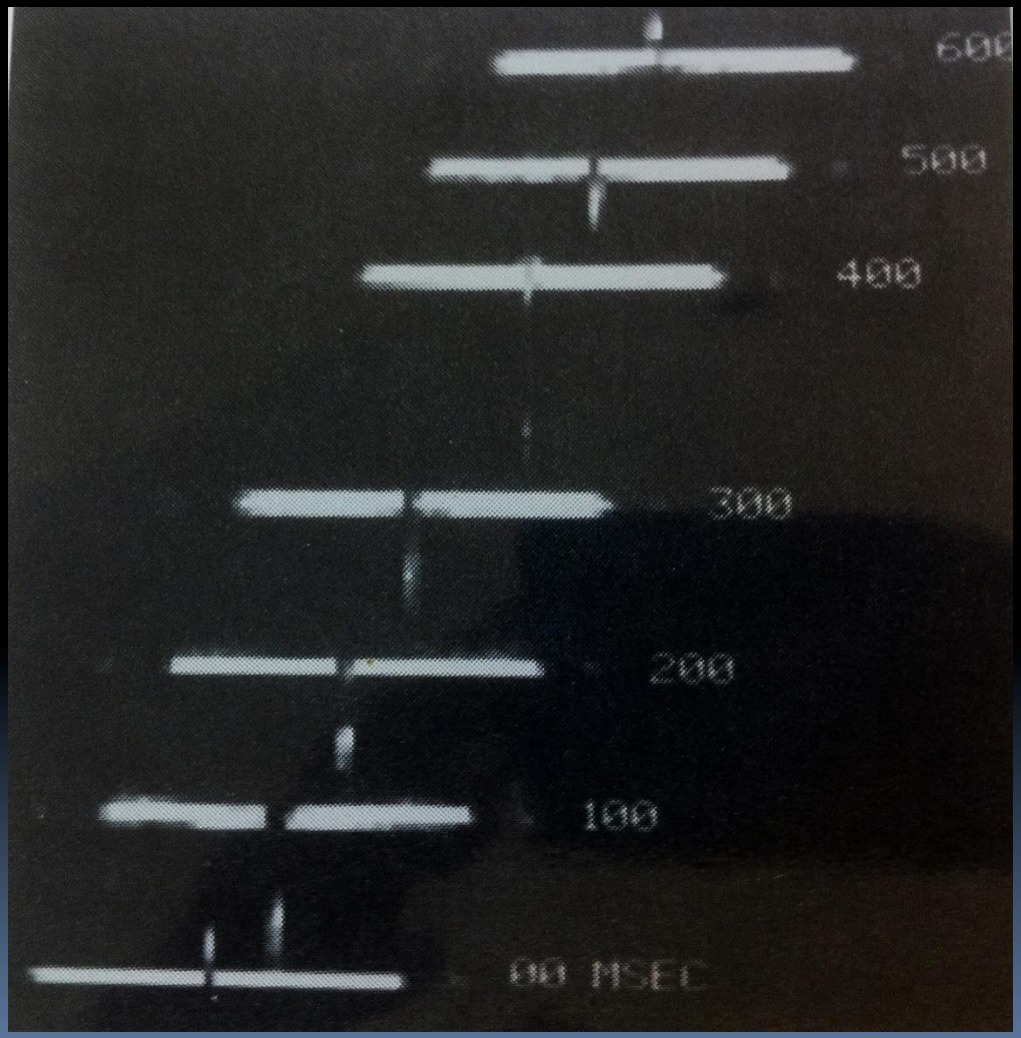
CSF Fourier velocity phase imaging



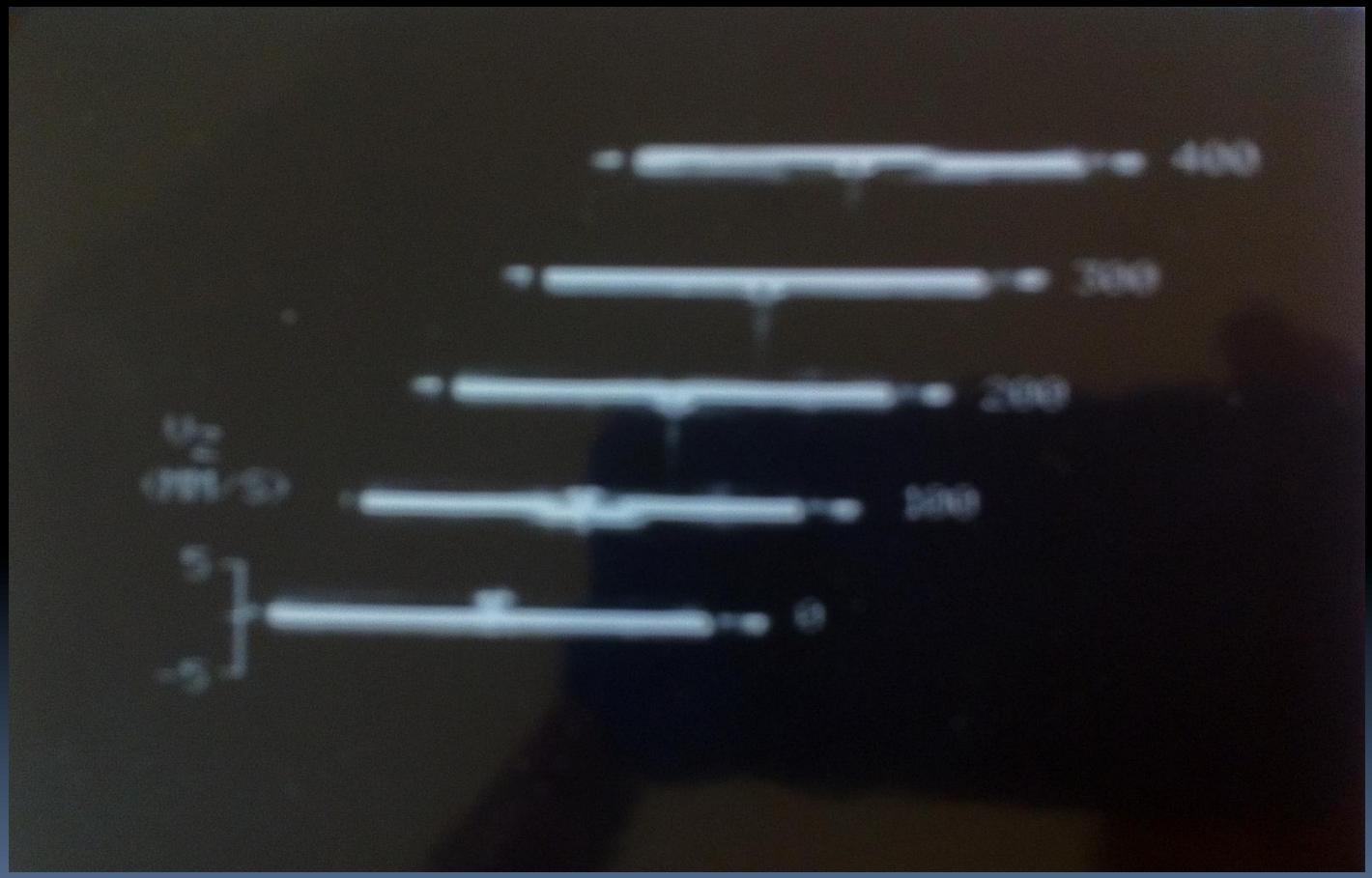
Feinberg and Mark, Radiology 1987



Feinberg and Mark, Radilogy 1987

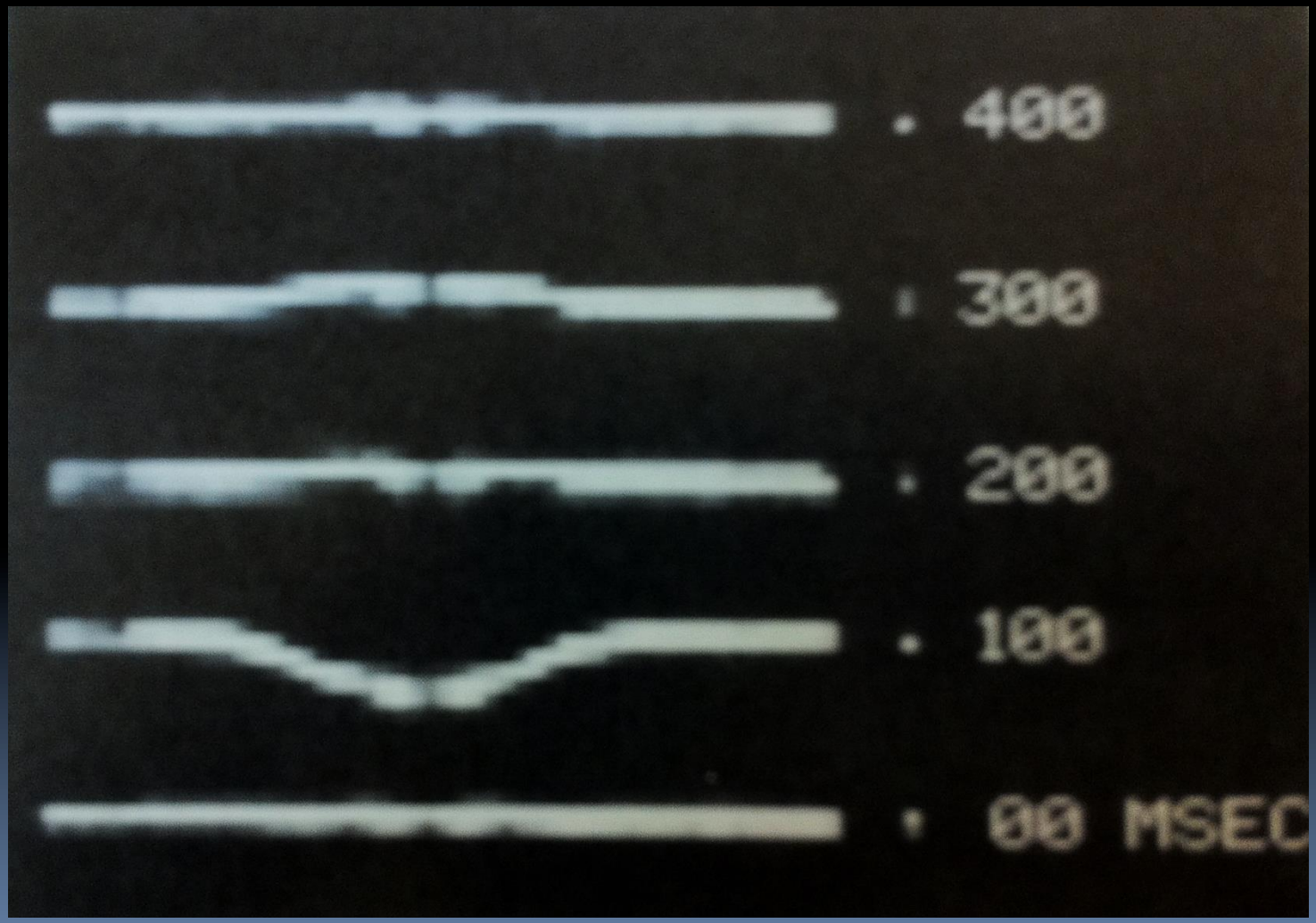


Feinberg and Mark, Radilogy 1987



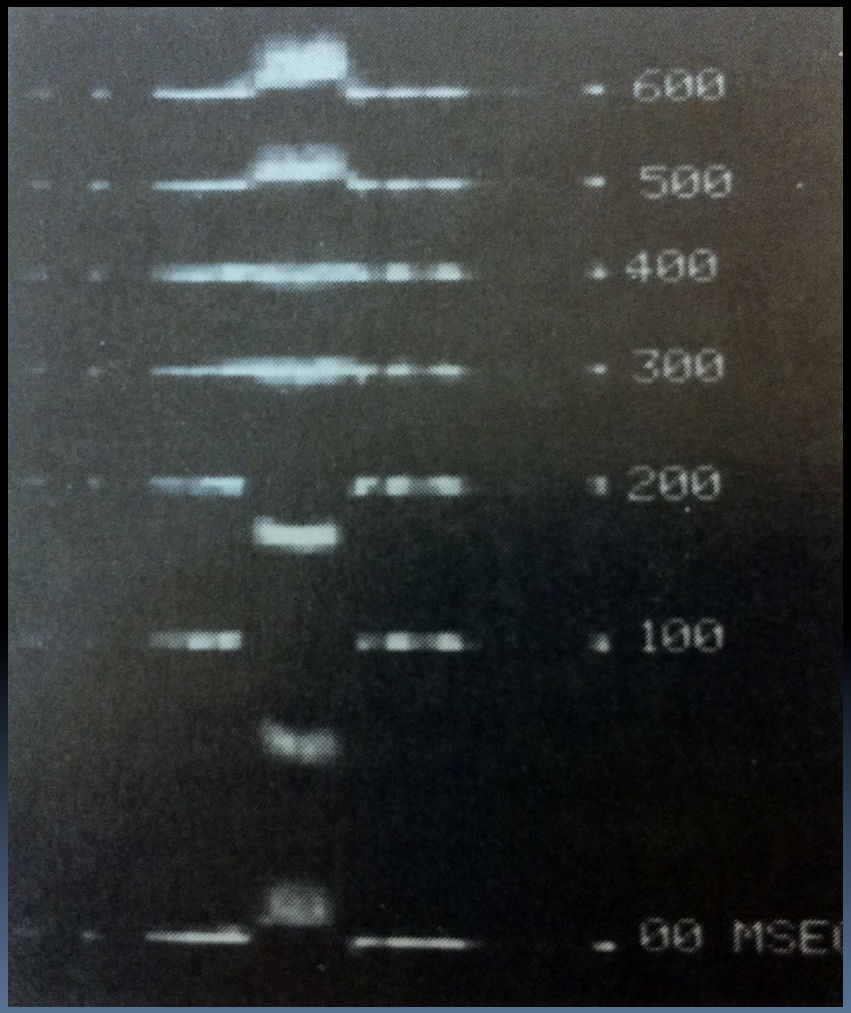
Feinberg and Mark, Radilogy 1987

Brain velocity - diencephalon



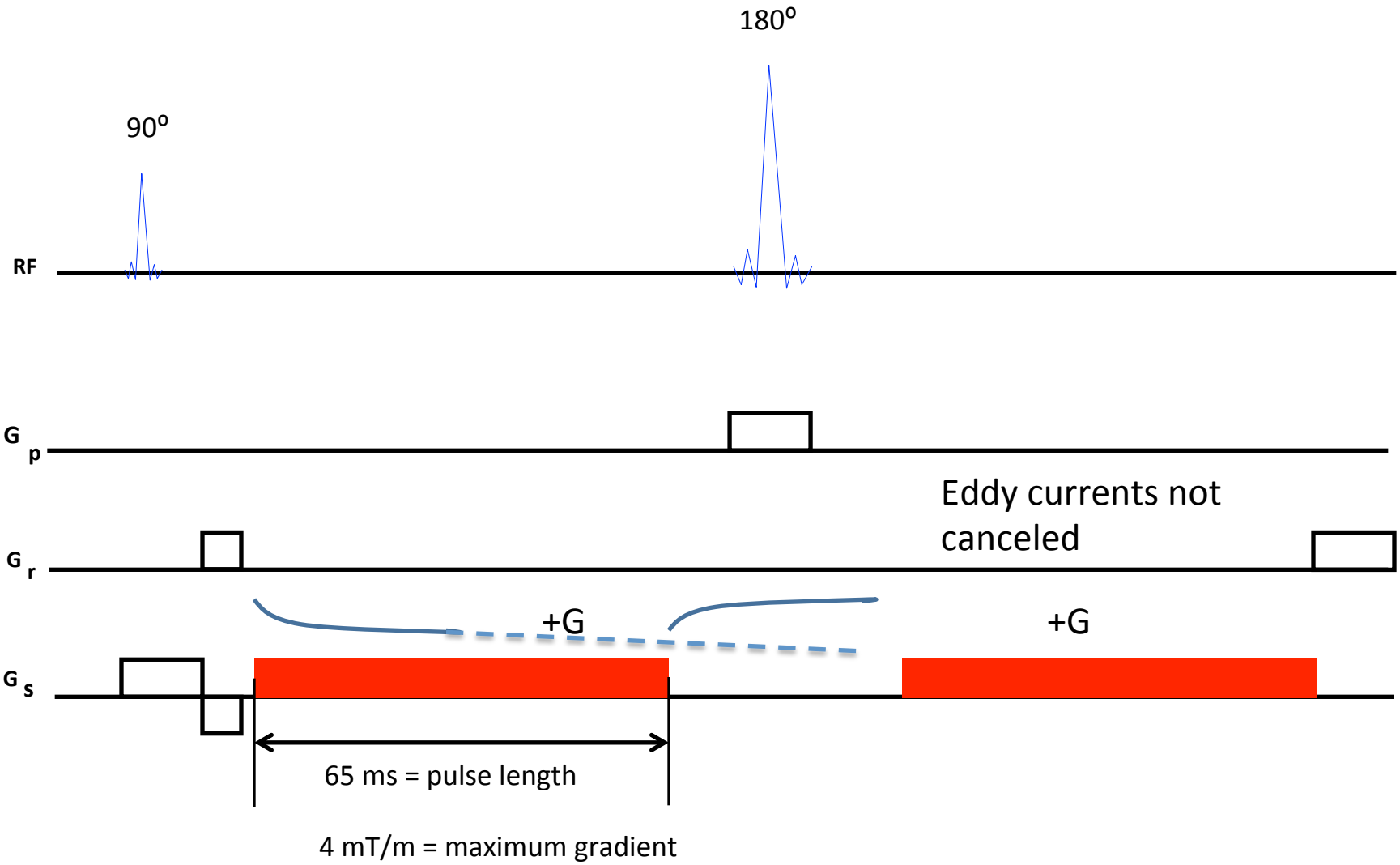
Feinberg and Mark, Radilogy 1987

cistern

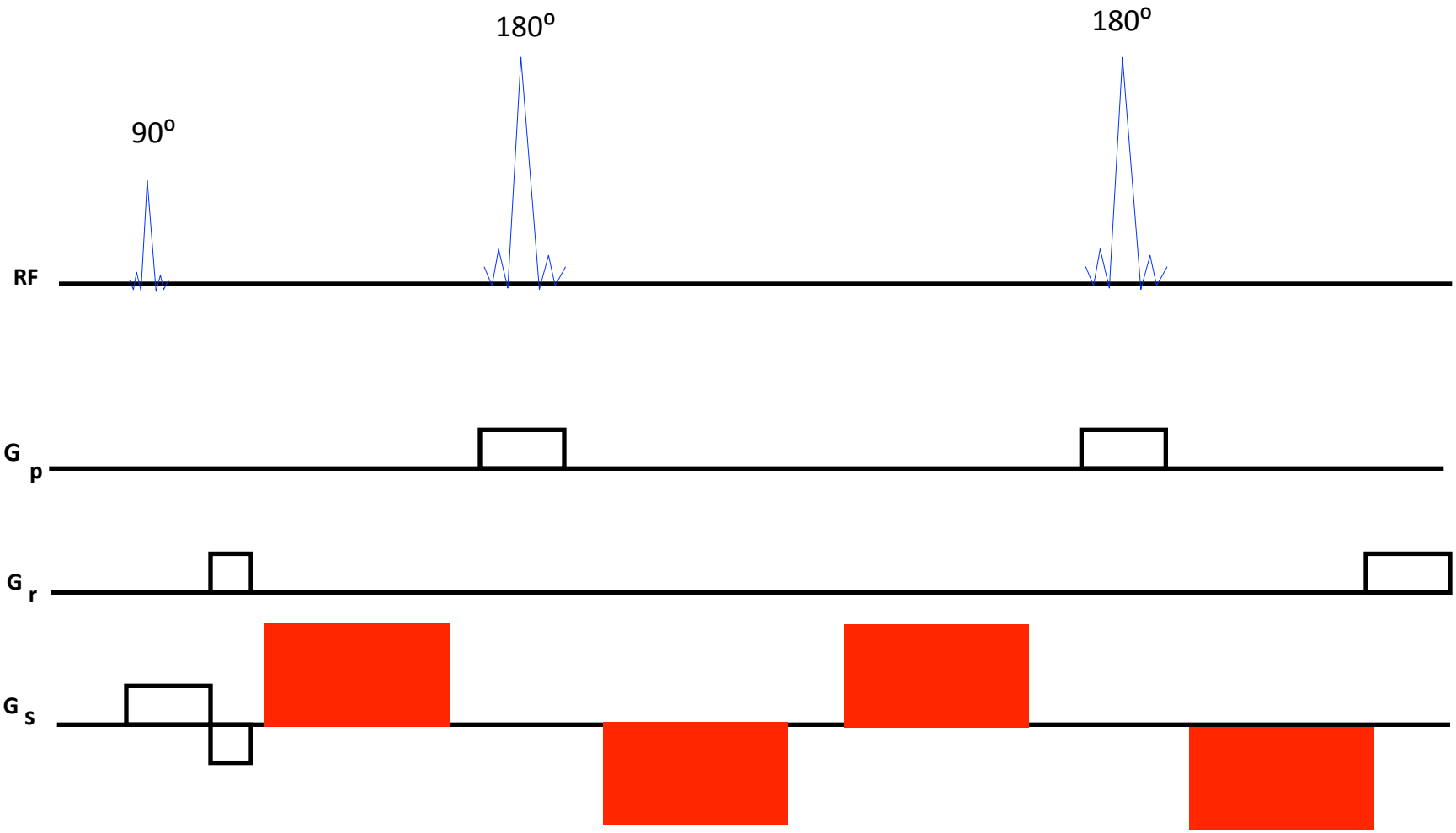


Feinberg and Mark, Radilogy 1987

Old Scanners had weak gradients requiring SE refocusing --> Eddy Currents



Twice Refocused SE diffusion and velocity (bipolar)



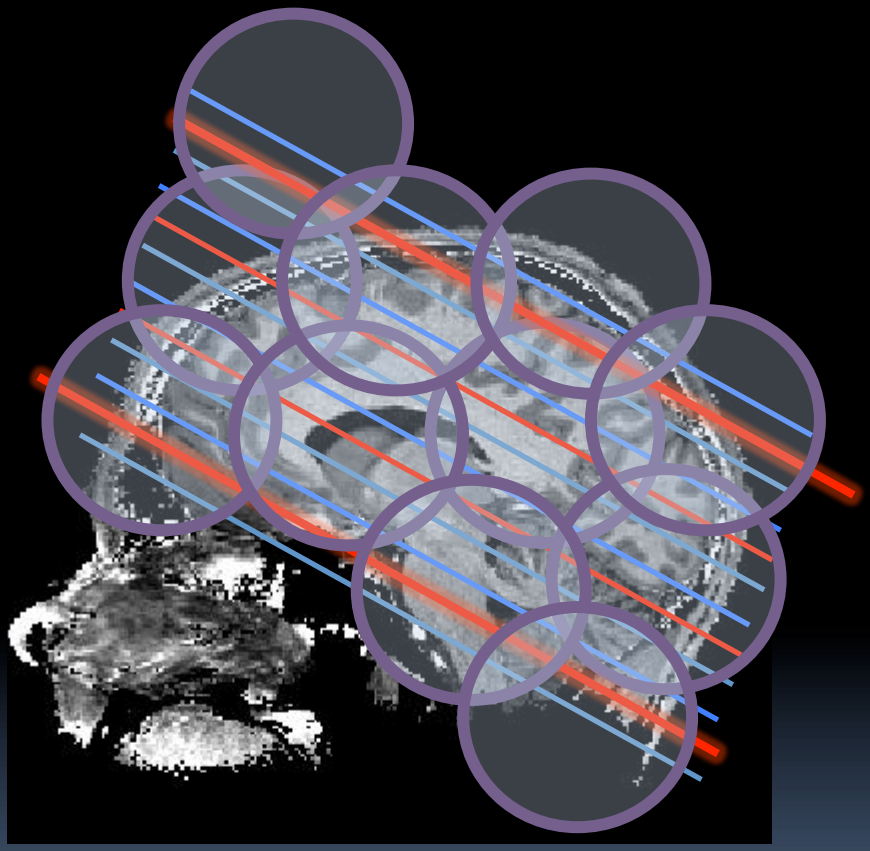
Feinberg and Jacob, MRM 1990

Simultaneous multi-slice Imaging using multibanded (MB) excitation pulses

- Excite ***multiple (MB)*** slices simultaneously

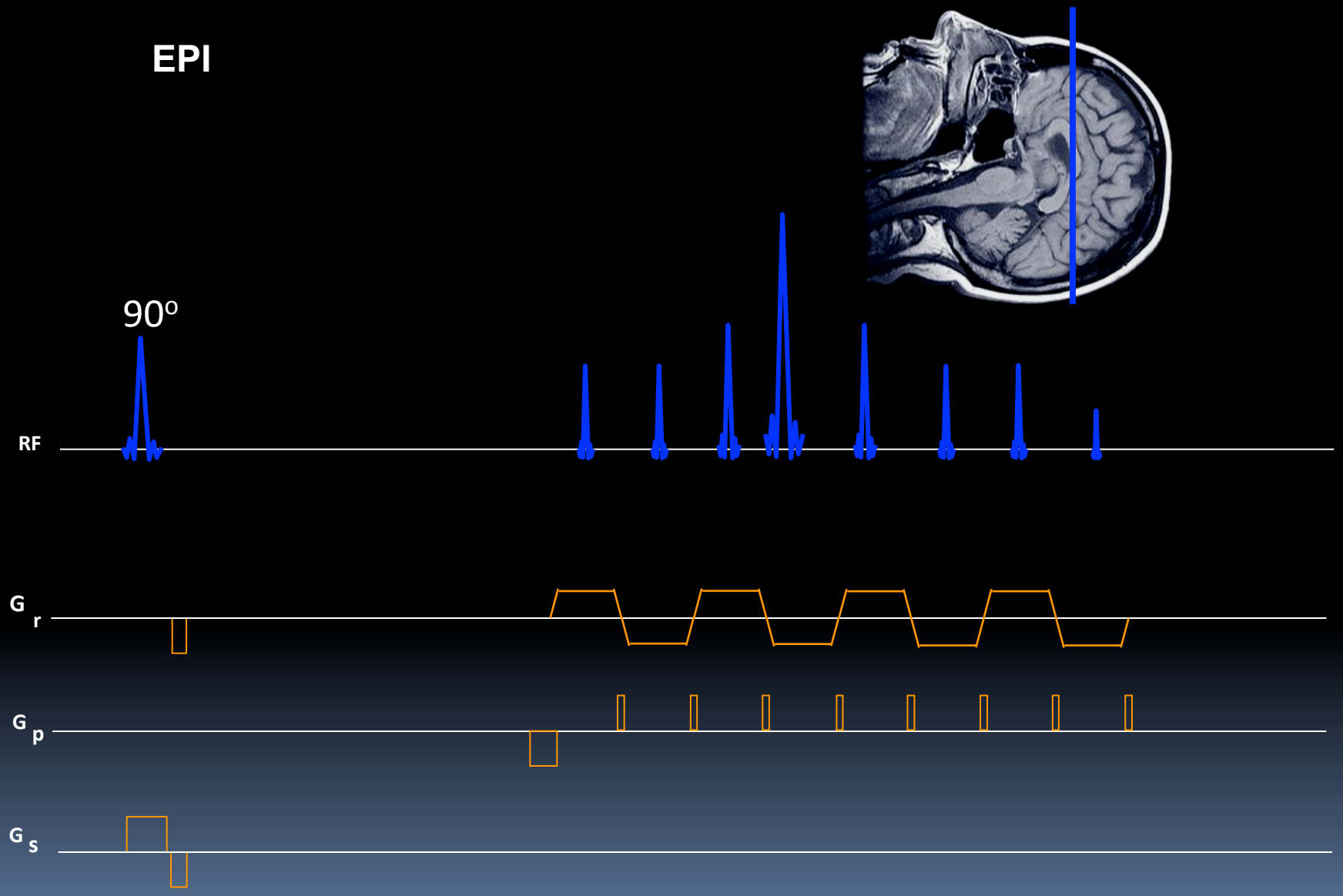
- Each coil yields a linear combination of signals from the different slices (weighted by sensitivity profiles)

- TR ~ 1 / MB



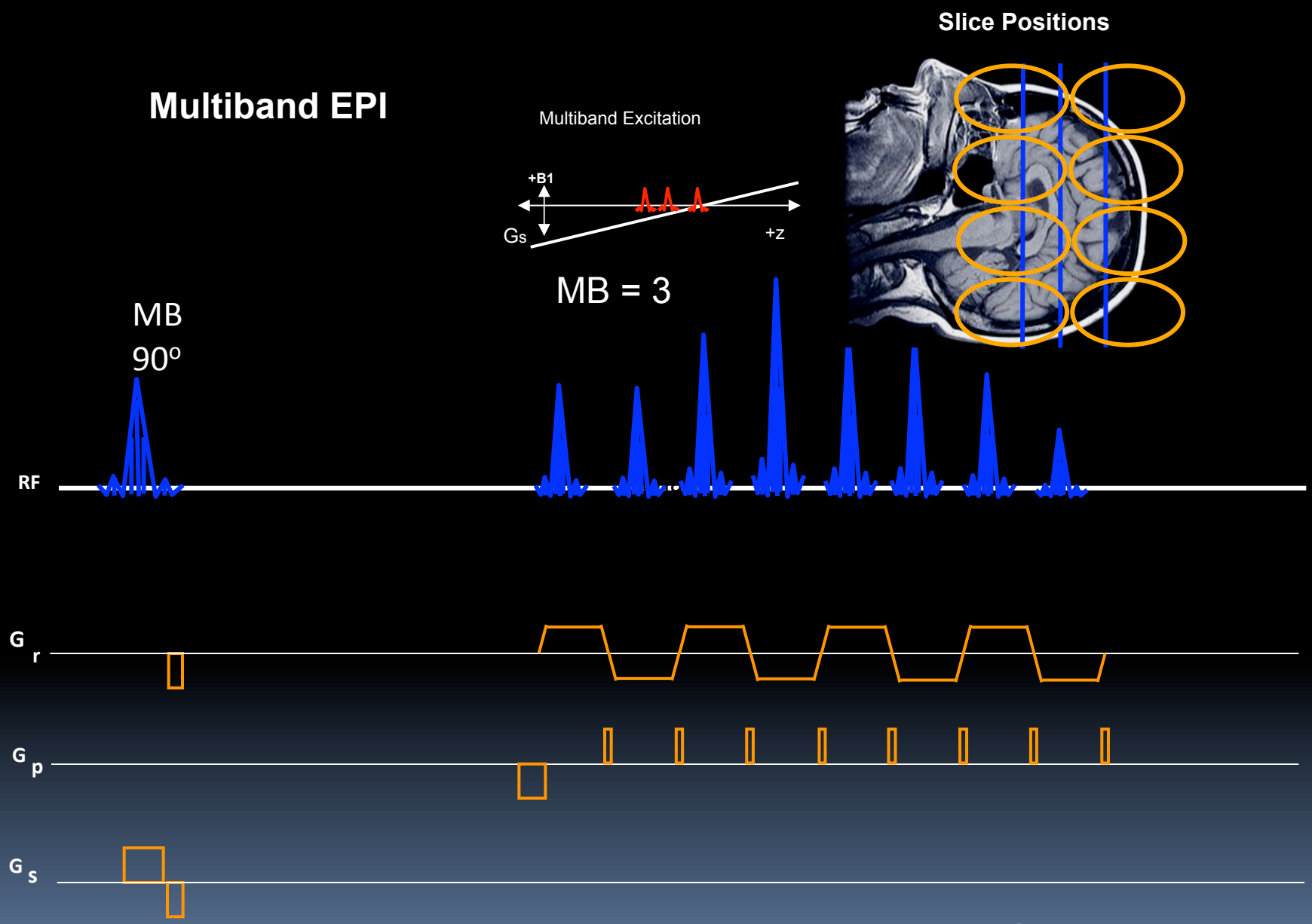
Larkman D et al, MRM 2001

EPI



Mansfield 1977

Multiband EPI

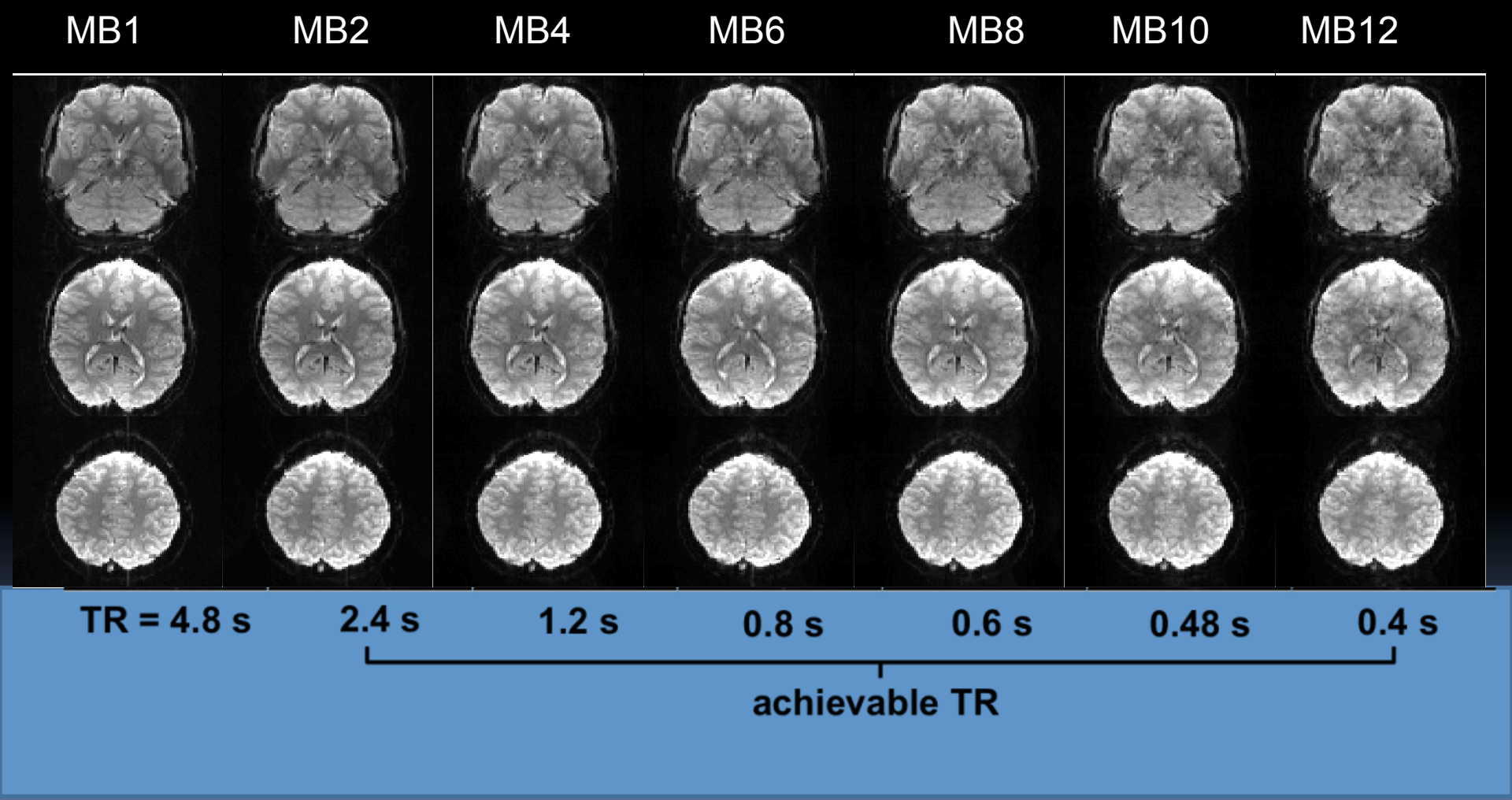


Nunes, Larkman et al ISMRM 2006
Moeller et al ISMRM 2008

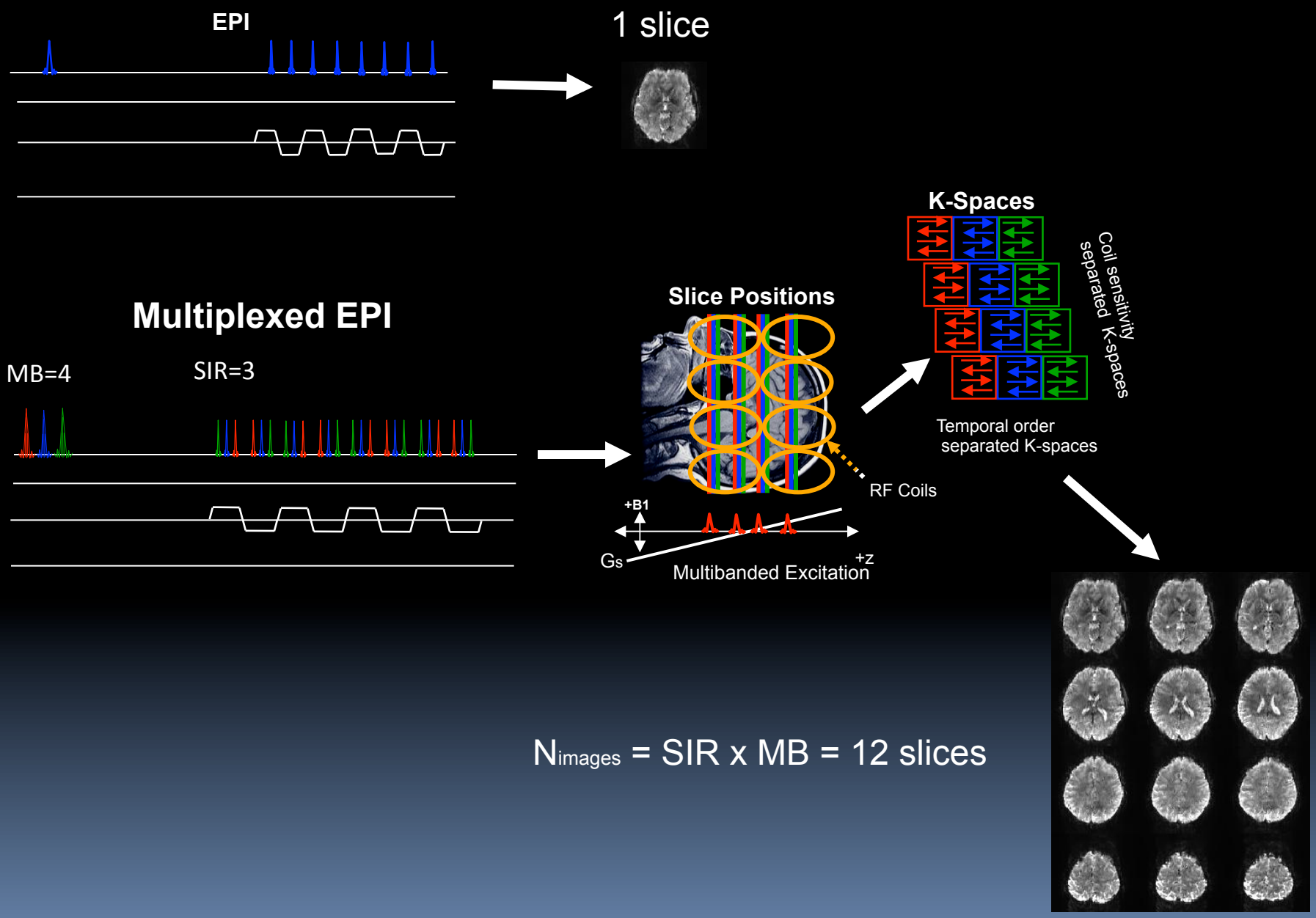
Multiband EPI with controlled aliasing

FOV shift=1/4, kw=7, isotropic 2mm, constant TR=2000ms

"Aligned" attention to Z-blip gradient moment nulling at Ko



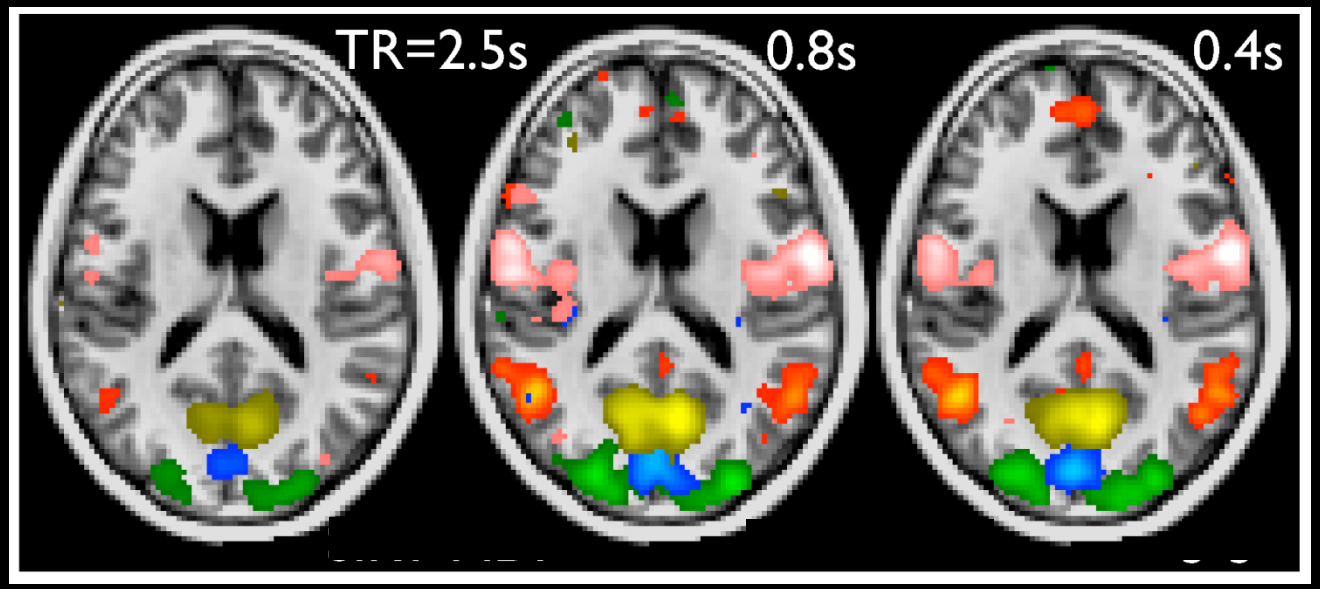
Xu, Moeller, Smith, Feinberg, Yacoub, Ugurbil (submitted)



N_{images} = SIR x MB = 12 slices

Feinberg DA, Moeller S, Smith SM, et al **PLoS ONE** 2010

Faster improved functional connectivity maps, 60-100% higher z-score

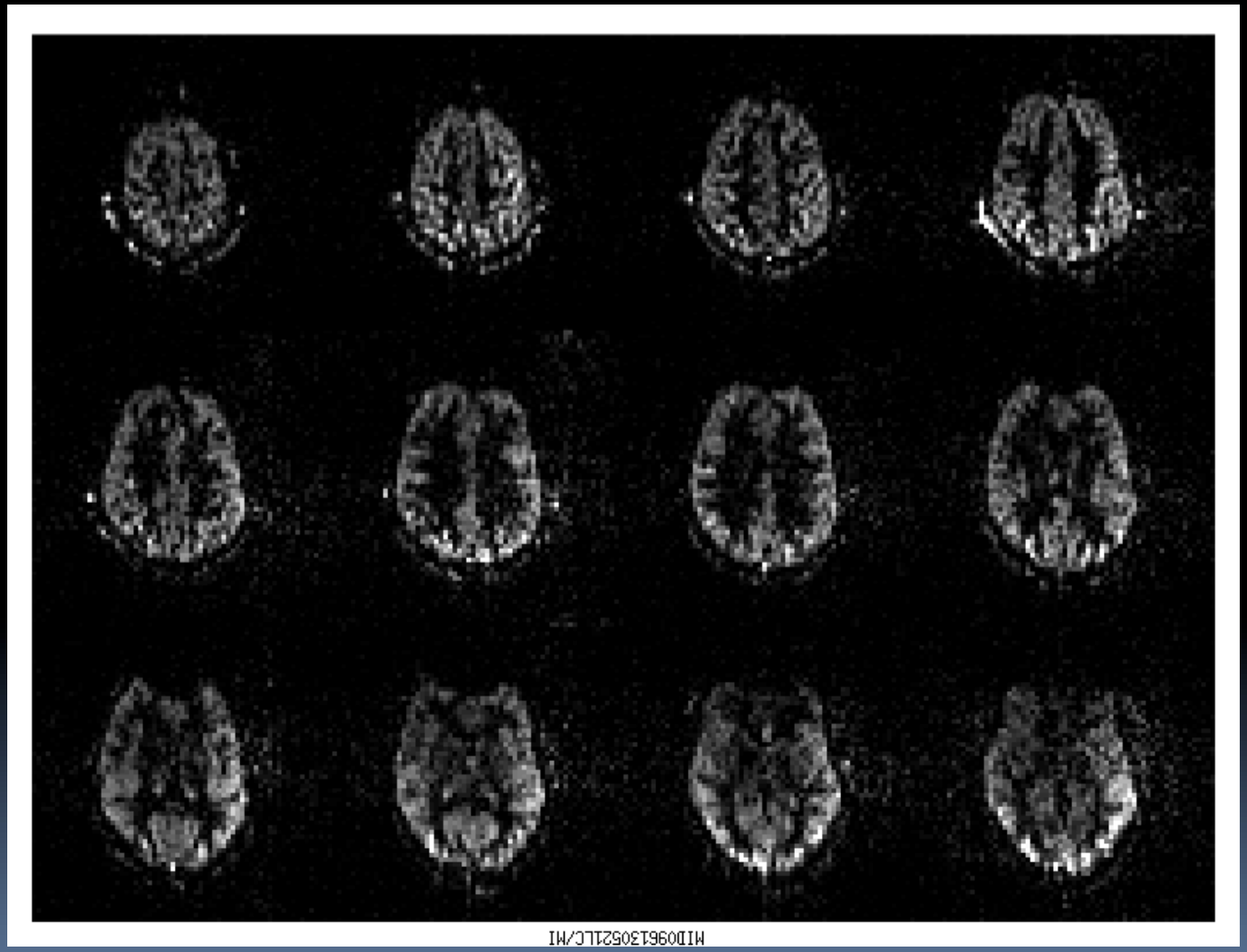


Simultaneous slices = 1 4 9

NIH HUMAN CONNECTOME PROJECT

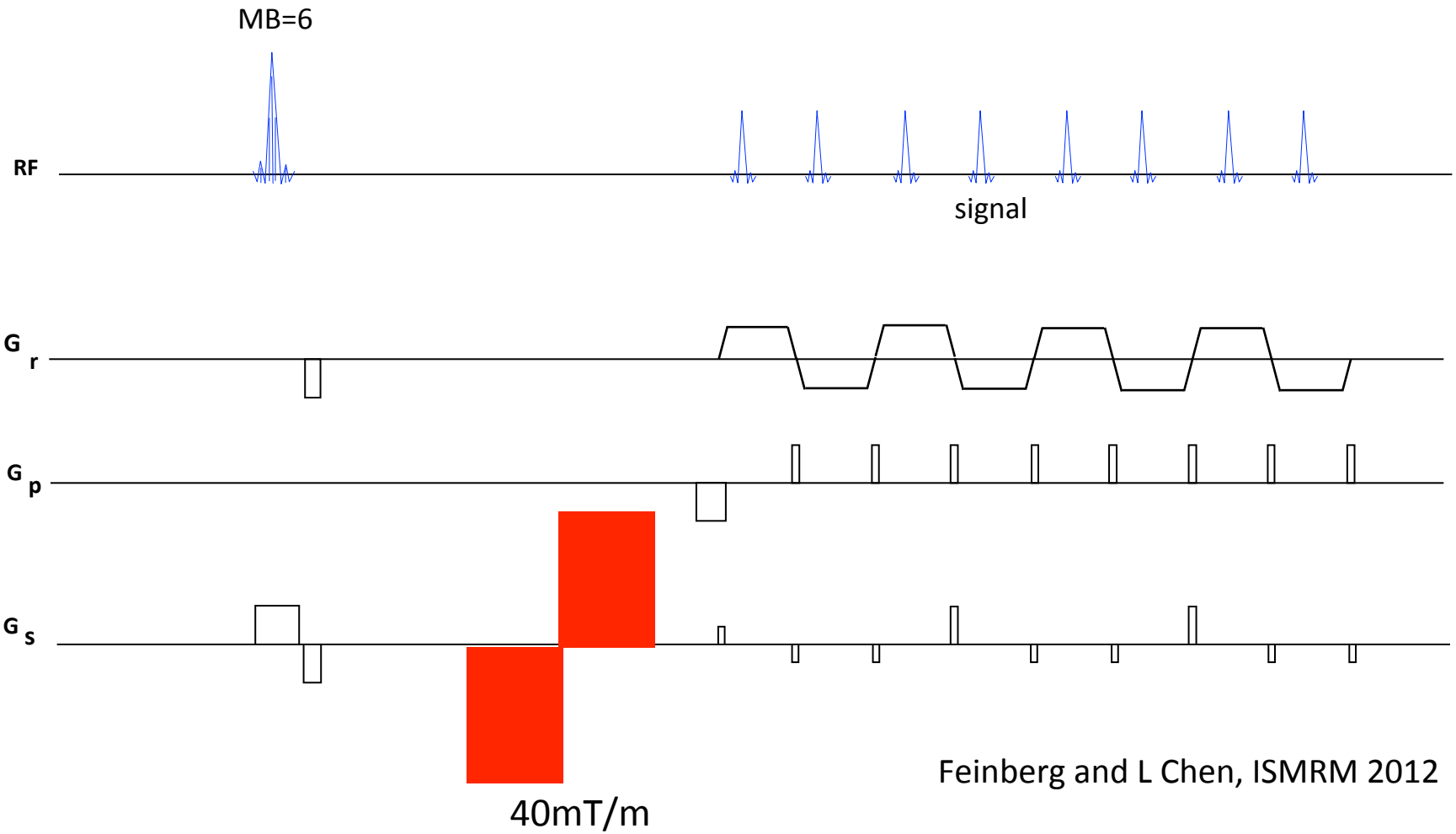
Multiplexed Echo Planar Imaging for Sub-Second Whole Brain FMRI and Fast Diffusion Imaging
DA. Feinberg, S. Moeller, S. Smith, E. Auerbach, S. Ramanna, M. Glasser, K. Miller, K. Ugurbil, E. Yacoub
PLoS ONE, 2010. 5(12): p. e1571

SMS ASL 2D EPI (MB=3)

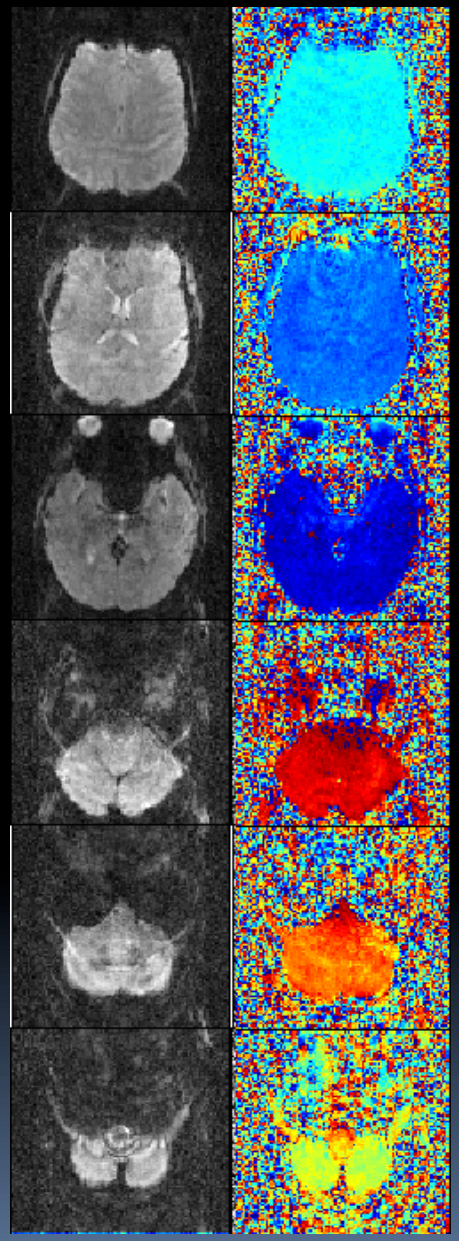


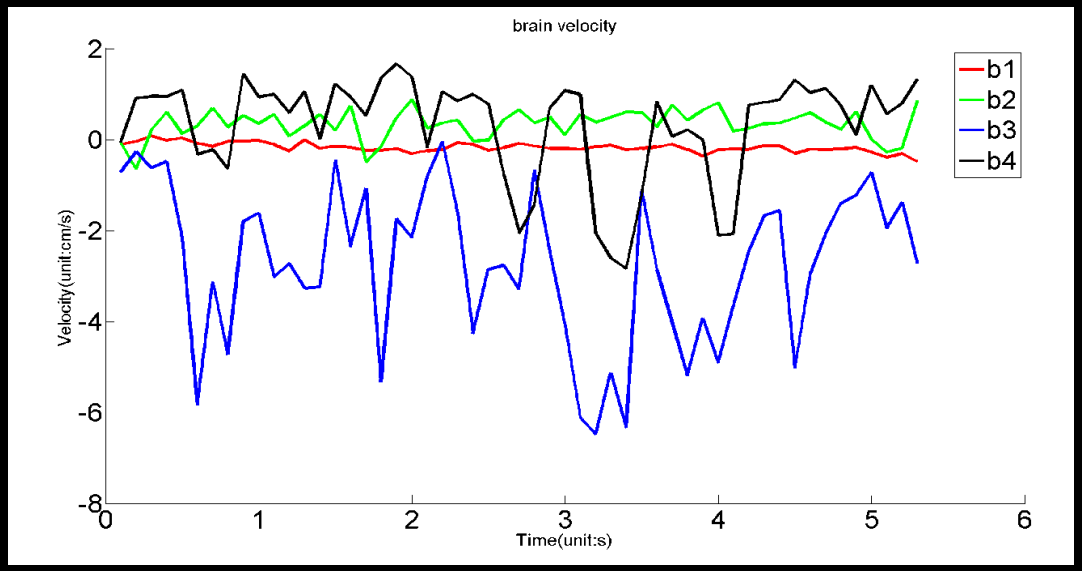
Feinberg and L Chen, (unpublished)

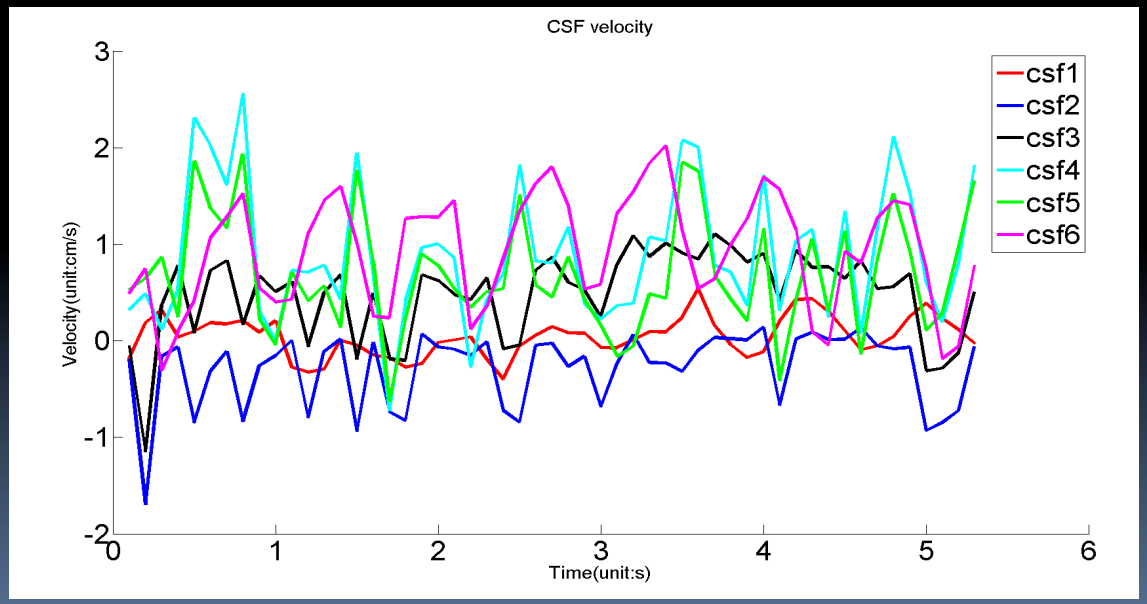
Simultaneous multi-slice CSF velocity imaging



Feinberg and L Chen, ISMRM 2012

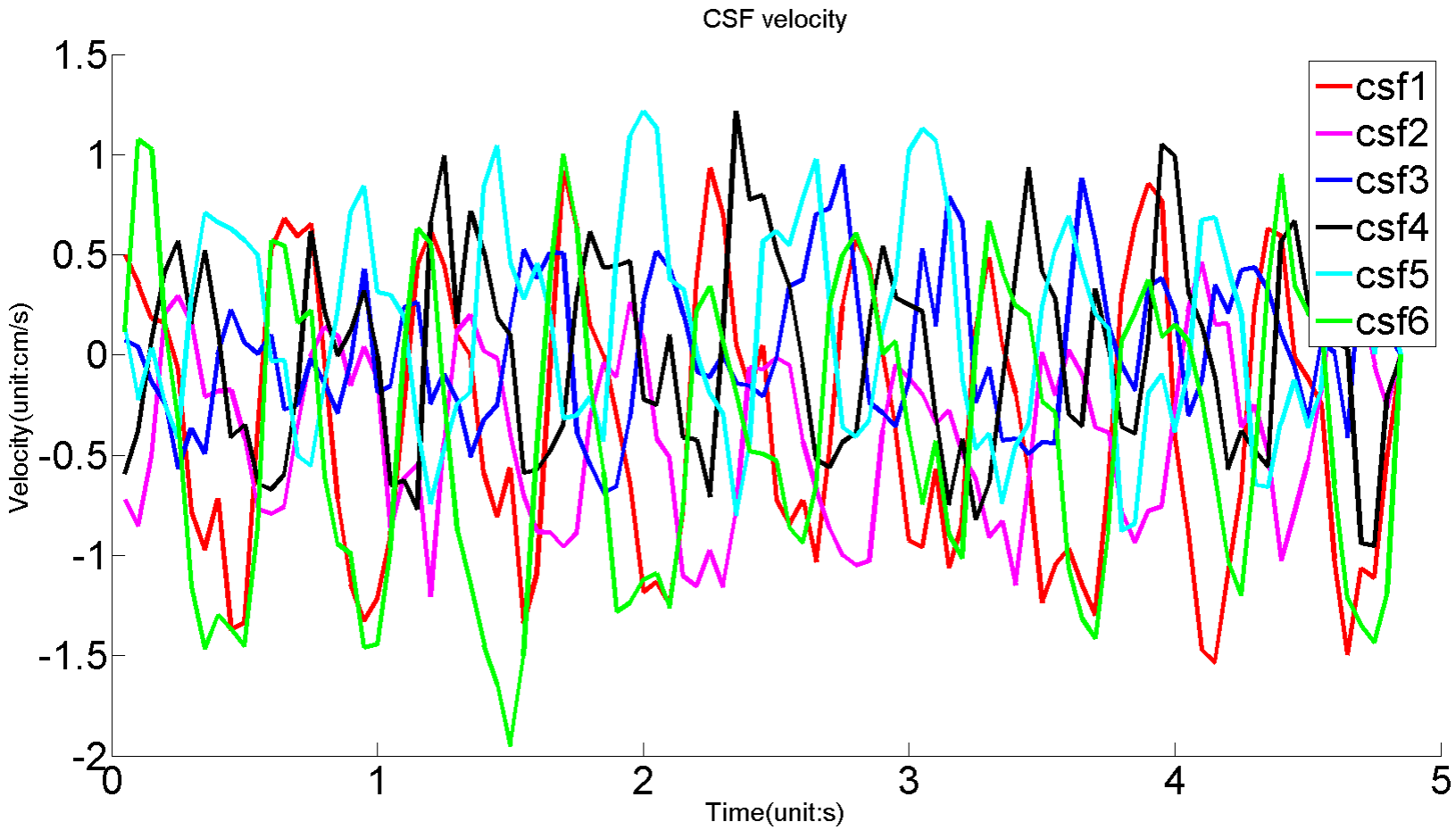


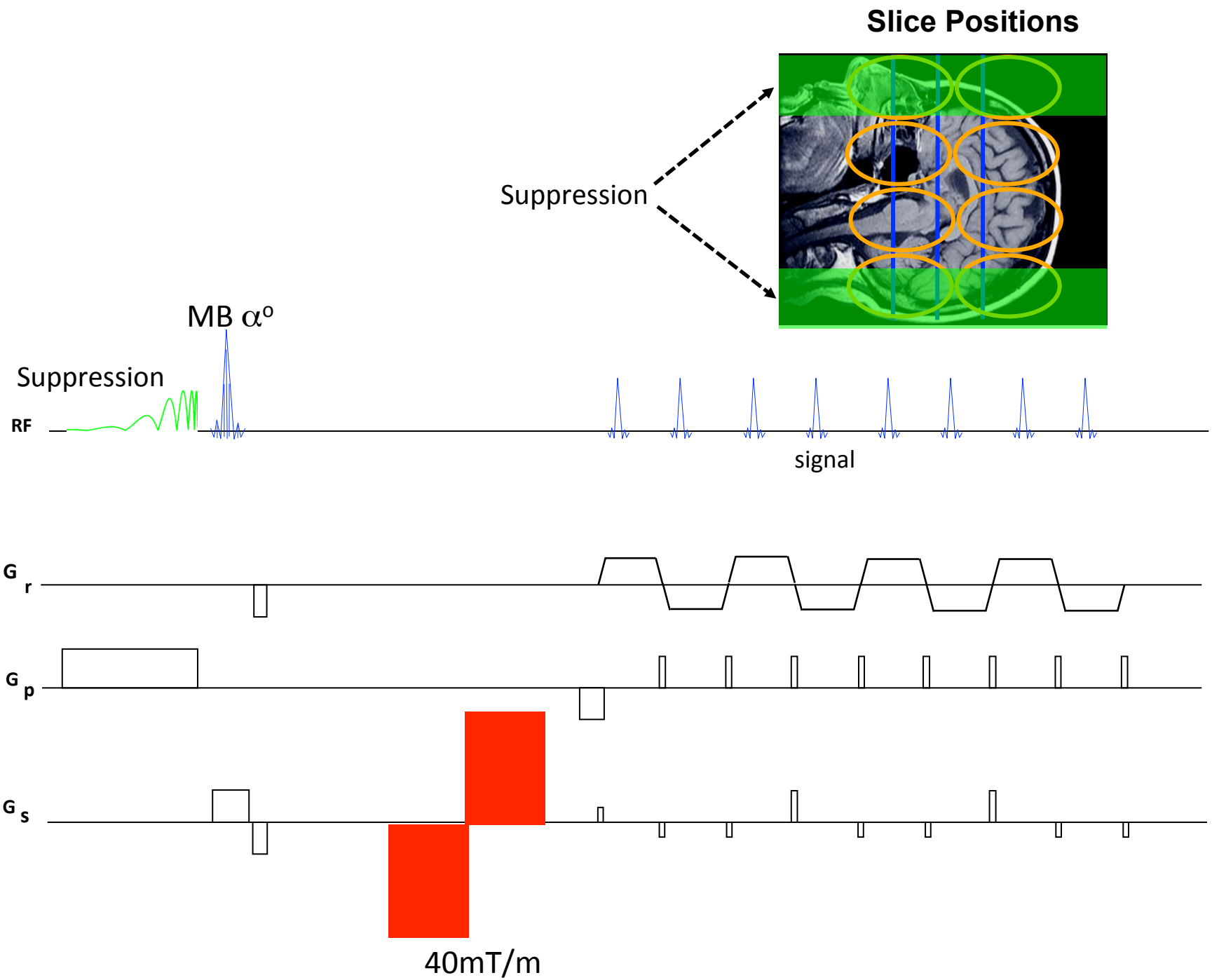




Feinberg and L Chen, ISMRM 2012

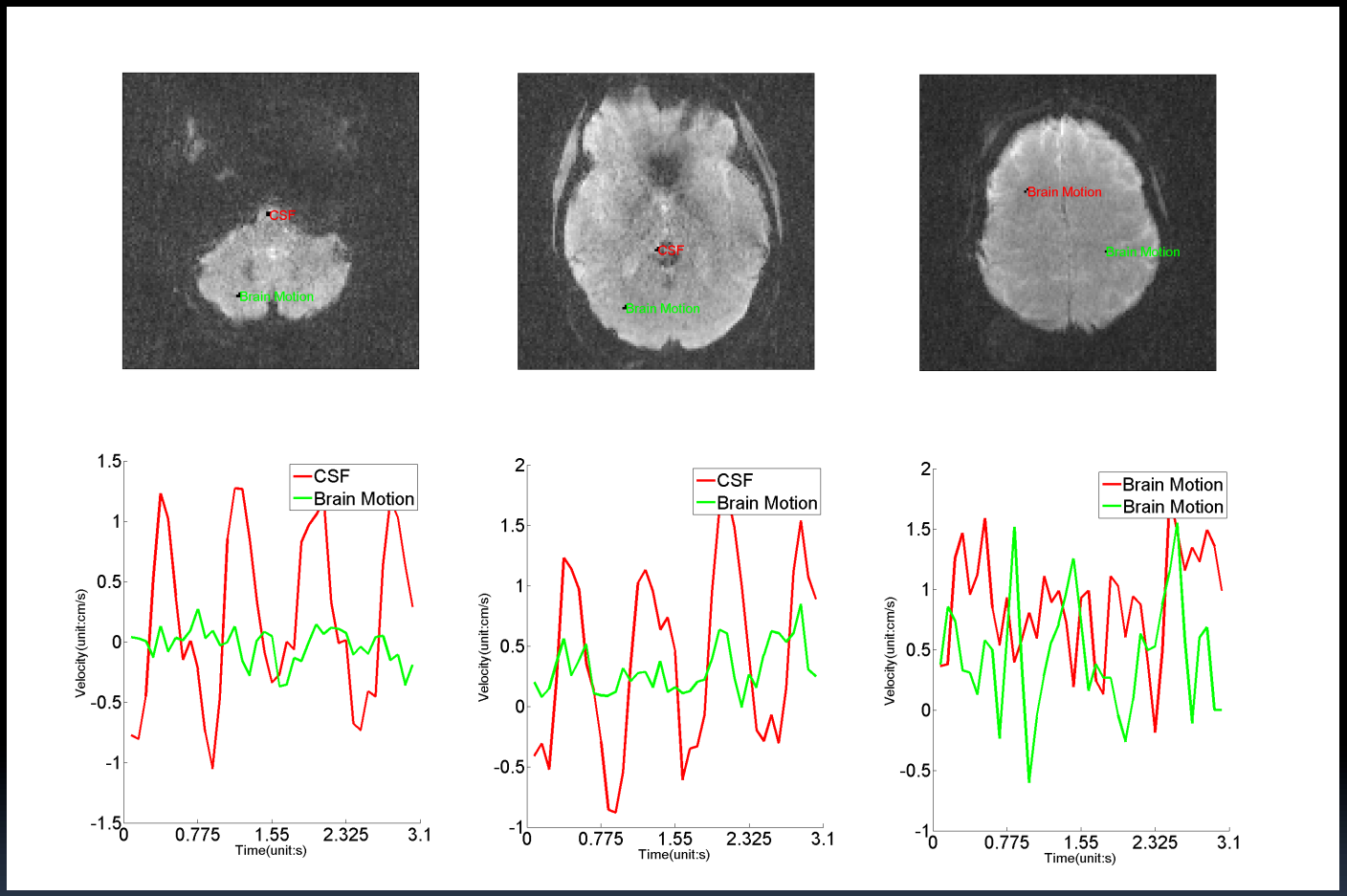
Csf velocity




Slice Positions
Suppression
MB αo
Suppression
RF
signal
G r
G p
G s
40mT/m

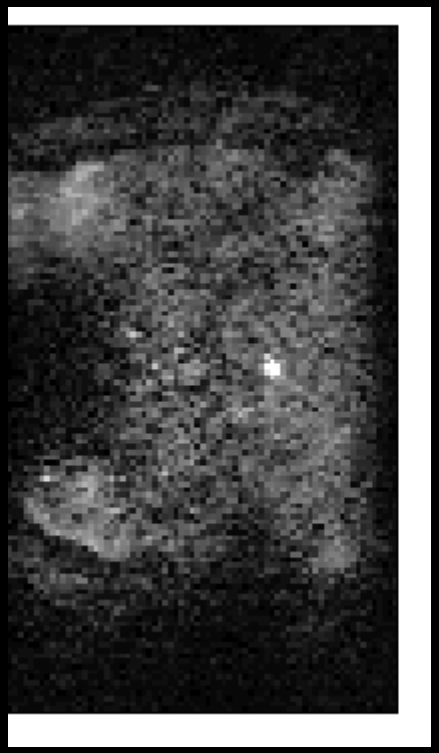
parameter

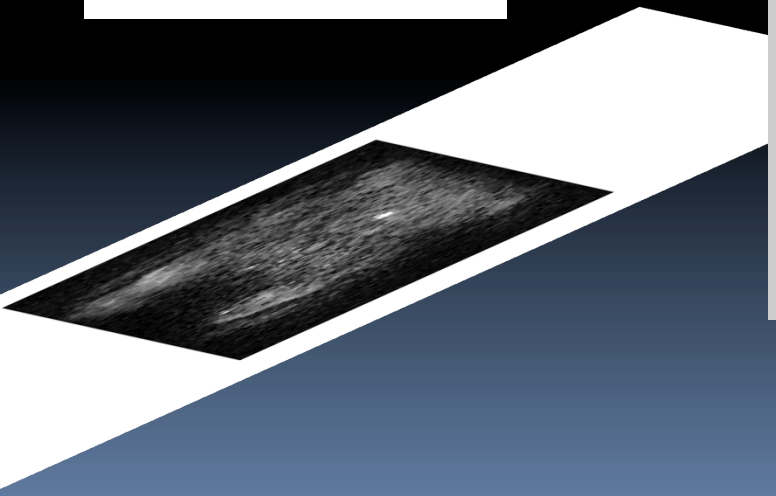
- TR=87ms;TE=38ms;Slice Thickness=3.0mm;
- PE FOV=120mm;RO FOV=192mm;
- BaseResolution=128;PELine=80;
- PE pFourier=6/8;
- in-plane res=1.50x1.50mm2
- Flip angle=25°

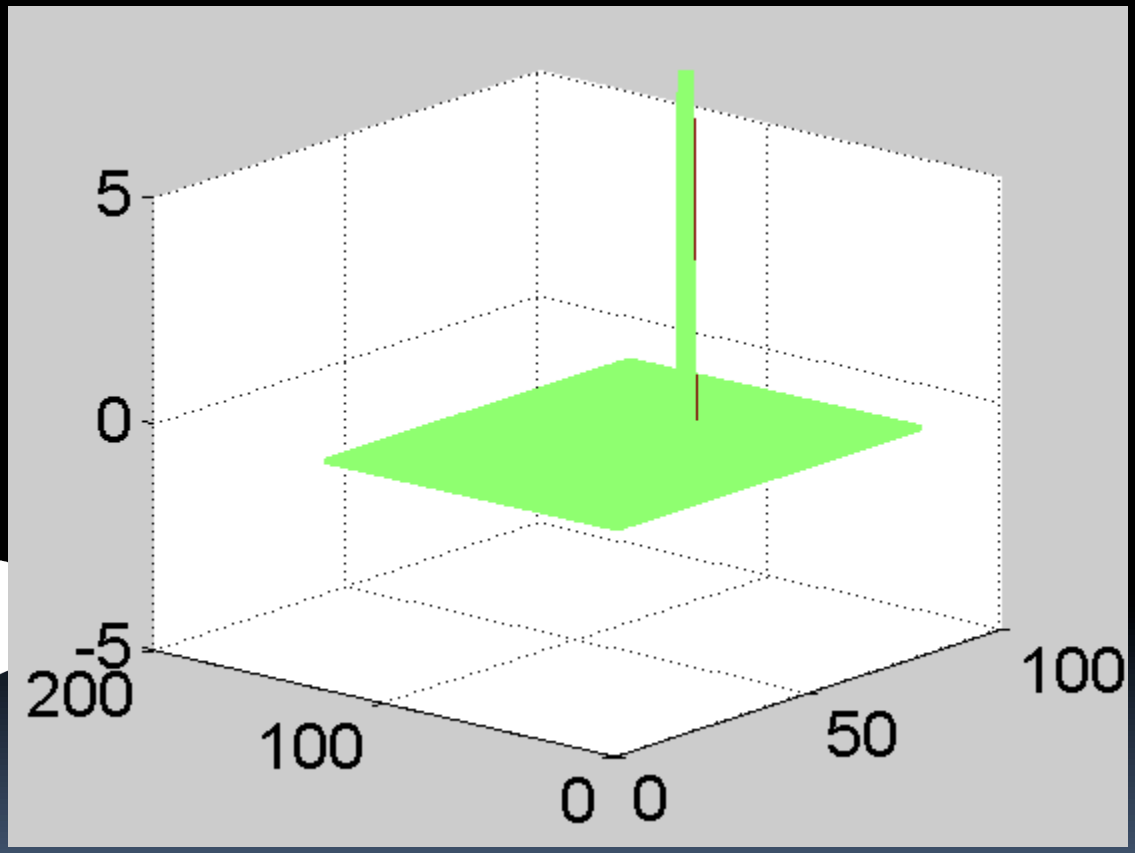


Real time magnitude images (upper row), brain motion velocity curves (red) and CSF curves (green). TR=77.5ms, VENC=5 cm/s. 13 frames/second, 3 slices acquired simultaneously, acquisition time≈3s.

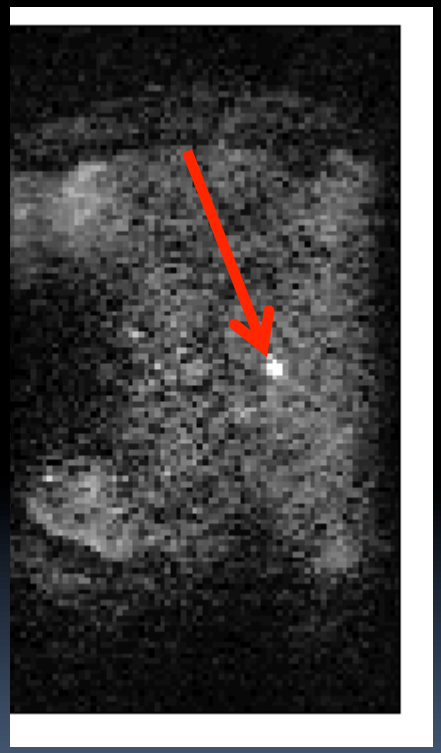
Slice for aqueduct

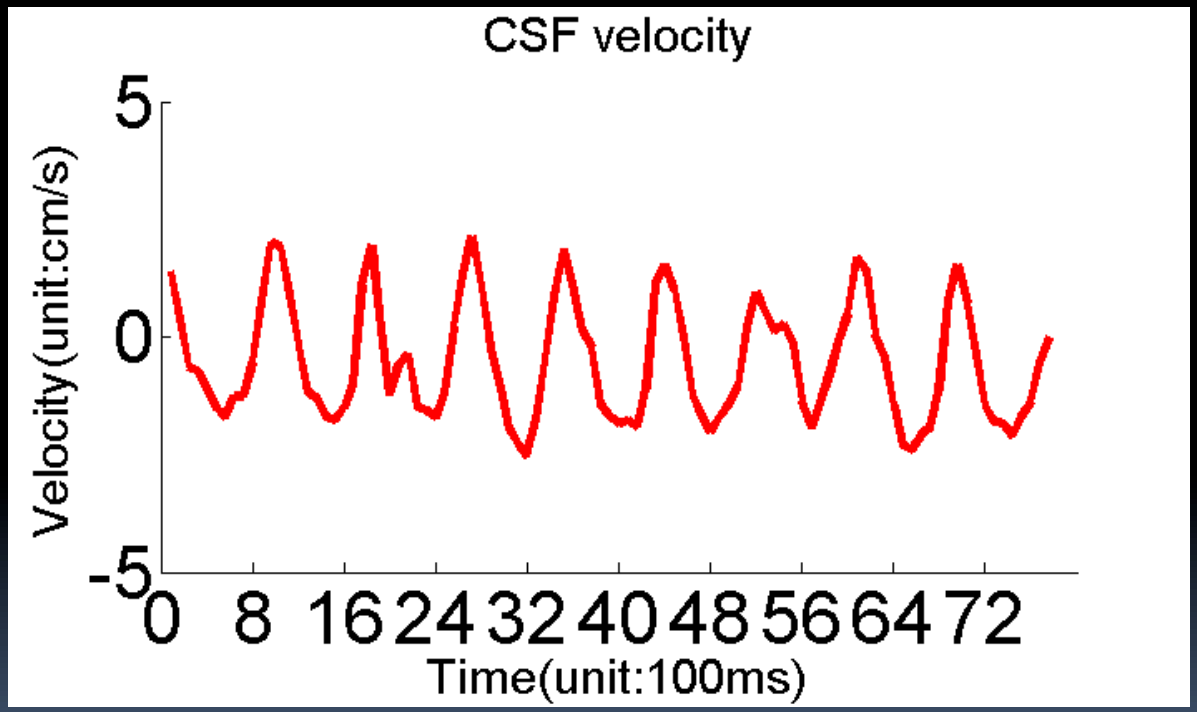




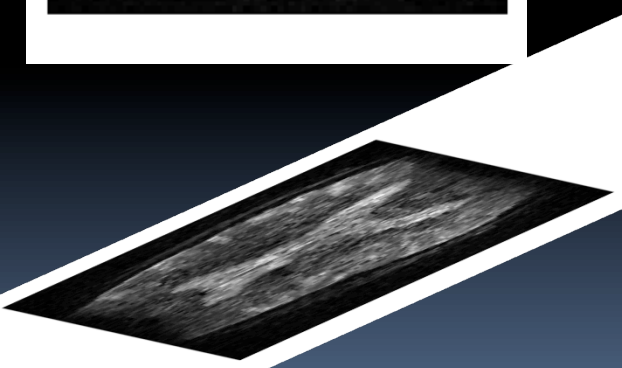


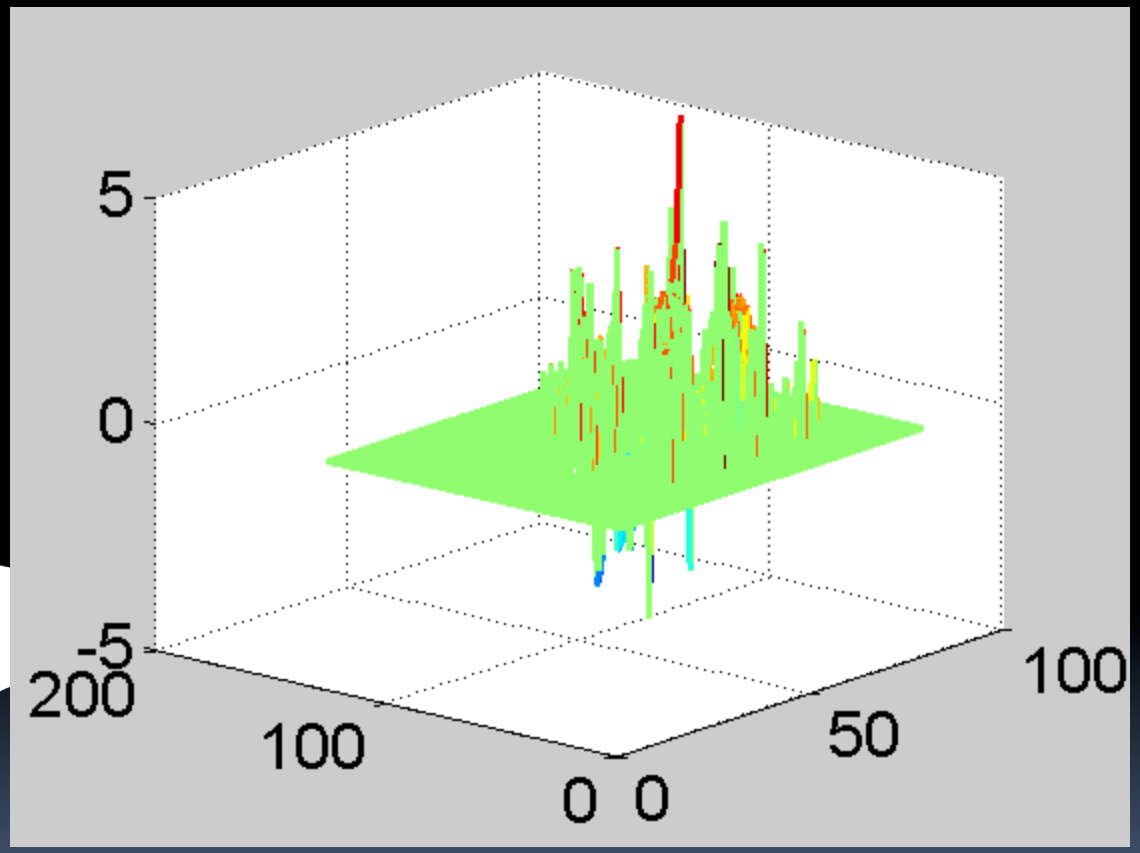
Slice for aqueduct



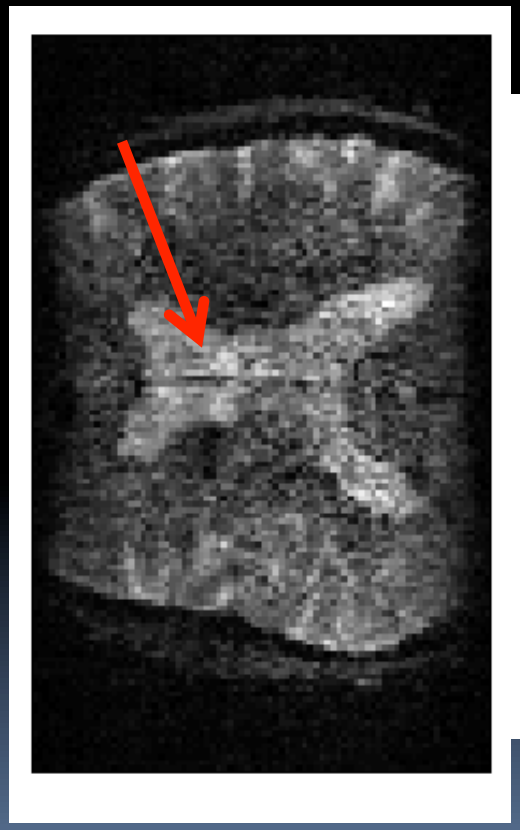


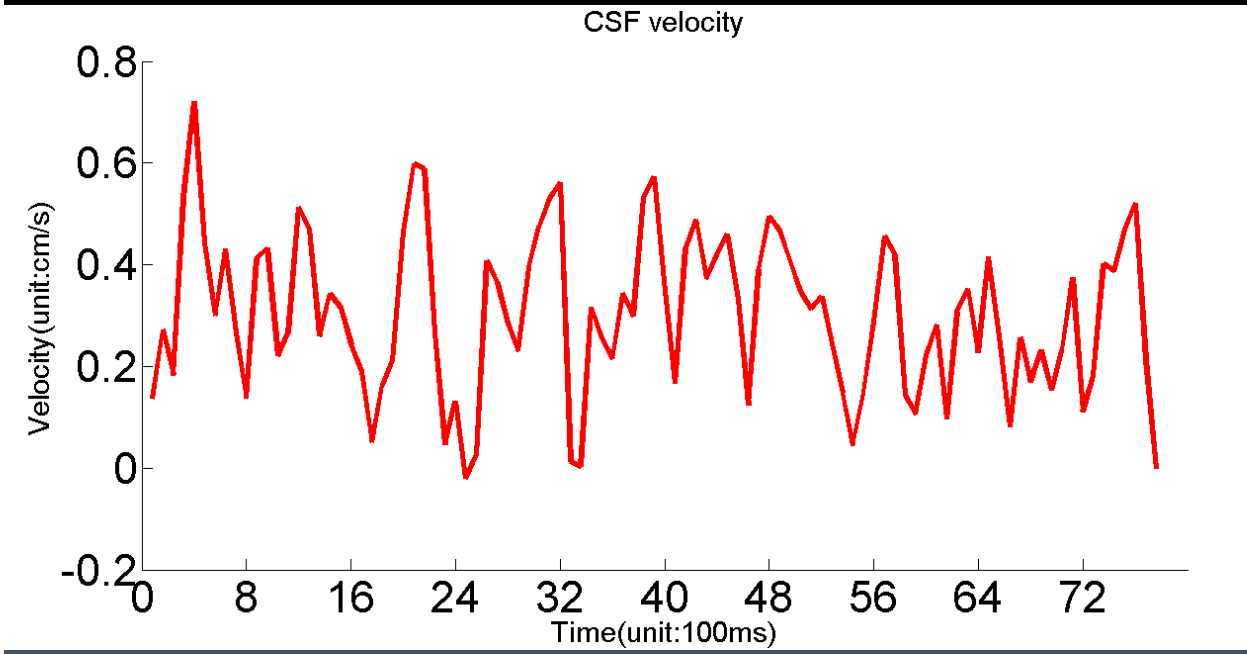
Slice for aqueduct





Slice for Lateral Ventricles





Future possible directions:

-Segmented acquisitions
-FLASH readout sequence
-Shared sliding echoes for higher temporal resolution
-Zoomed resolution

CONCLUSION:

Simultaneous measures of CSF velocity (and blood and brain velocity) in real-time imaging is achievable