# Methods for improving CT and MRI image quality

MIR & MRI Laboratory

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# What are the problems?

CT

**X-ray**
**⇒Dose reduction**

MRI

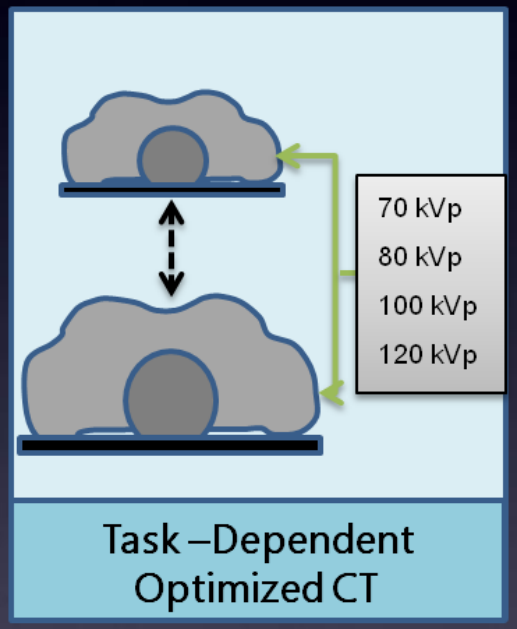
**Long scan time**
**⇒Scan time reduction**

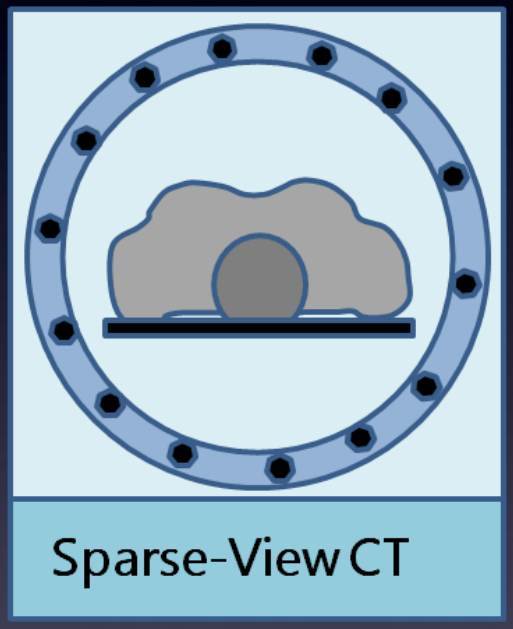
# CT

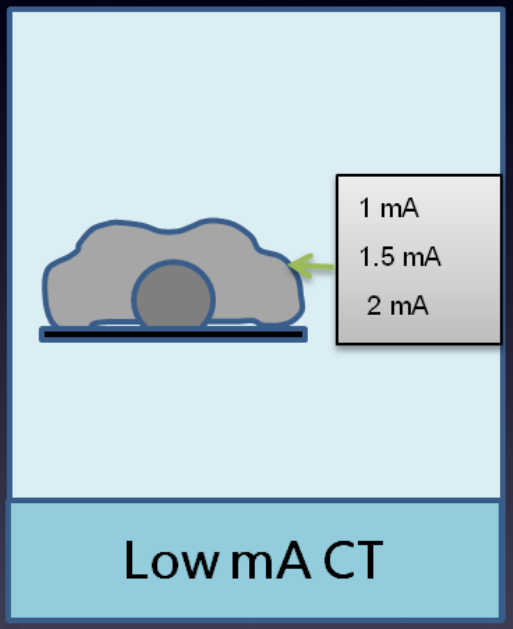
**X-ray**

**⇒Dose reduction**

# Dose reduction techniques



# Methods for improving image quality with low dose

- Iterative reconstruction algorithm
- Many view under sampling
- Region of interest(ROI) imaging

# Iterative reconstruction algorithm

- Algorithm that find solution, which is original image in this case, by iteratively with minimum error
- Compare to analytic algorithm, iterative algorithm can solve ill-posed problem also

# TV Minimization

| **POCS** | **TV** |
| --- | --- |
| **ART + Positivity constraint** | |
| $\left(\text{Measure projection} - \text{Calculated projection}\right) < \varepsilon$ | $\|f_{s,t}\|_{TV} = \sum_{s,t} \sqrt{(f_{s,t} - f_{s-l,t})^2 + (f_{s,t} - f_{s,t-l})^2}$ <br> s,t is pixels in image f |

Accurate image reconstruction from few-views and limited-angle data in divergent-beam CT
An algorithm for total variation minimization and applications

# TV Minimization

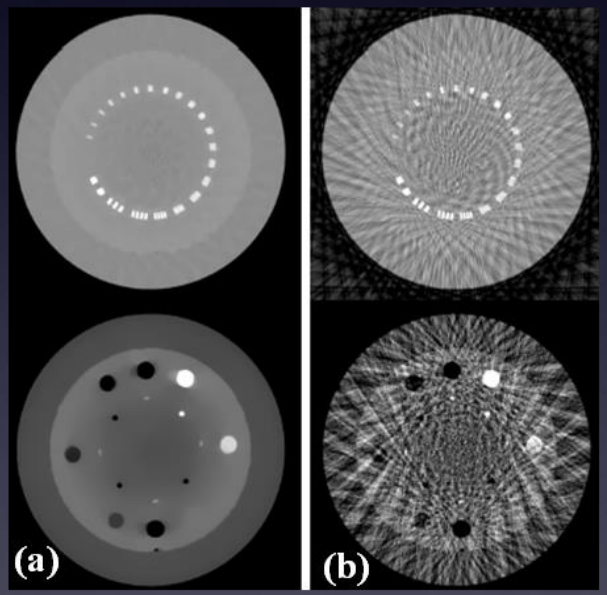
$$\overrightarrow{f^*} = \underbrace{argmin\left|M\vec{f} - \tilde{g}_{data}\right|^2}_{\text{POCS}} + \underbrace{\tau\left\|\vec{f}\right\|_{TV}}_{\text{TV}}$$

$\tau$ : Scaling term

Accurate image reconstruction from few-views and limited-angle data in divergent-beam CT
An algorithm for total variation minimization and applications

# Reconstruction with TV min. algorithm

- Compare to analytic reconstruction algorithm(FBP, FDK), TV minimization shows better reconstruct image from insufficient data



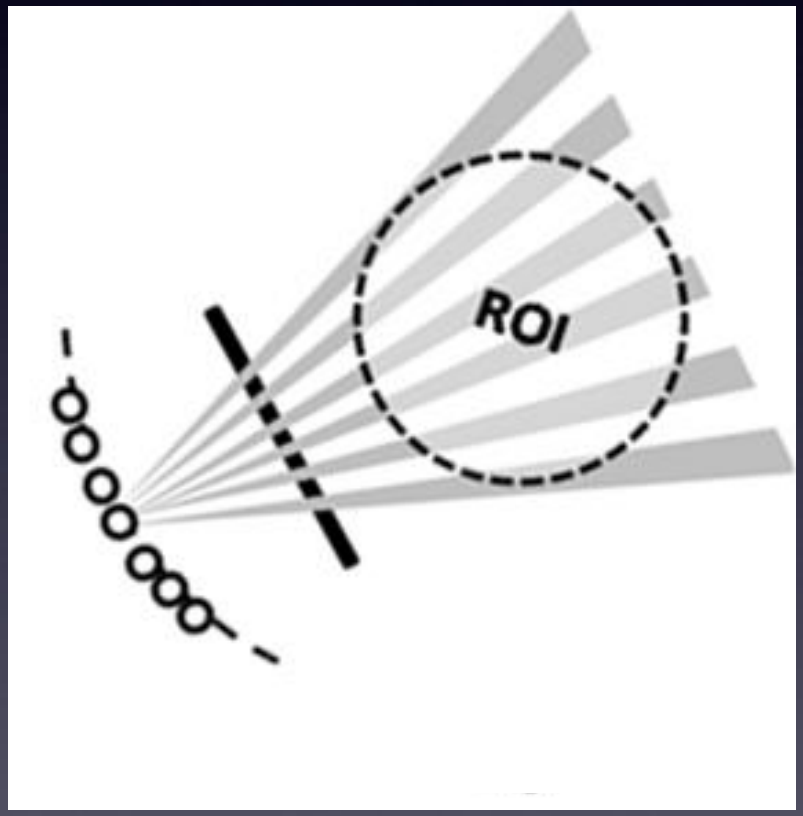

Reconstruction with TV

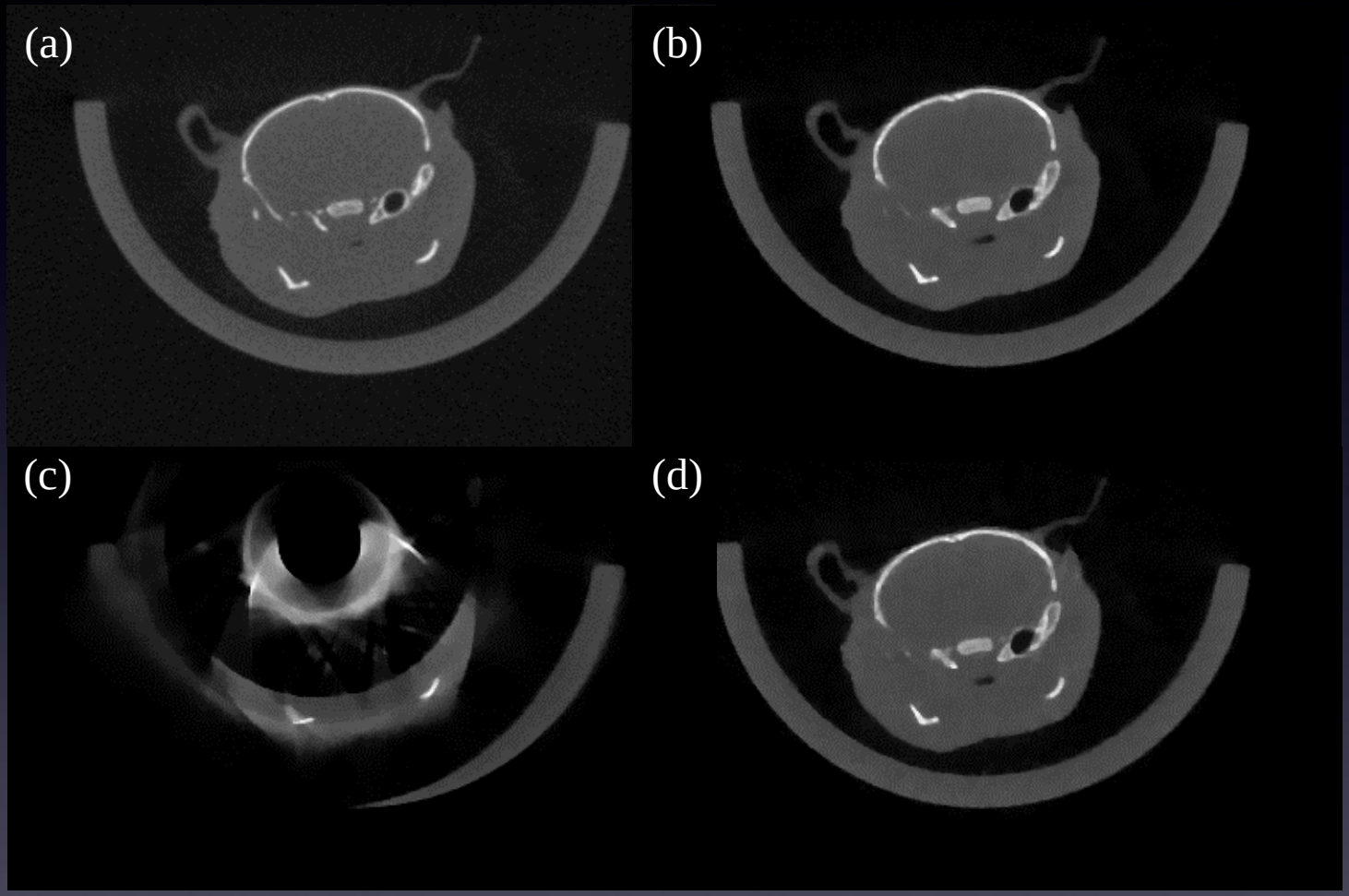
Reconstruction with FDK

Using 40 views of total image

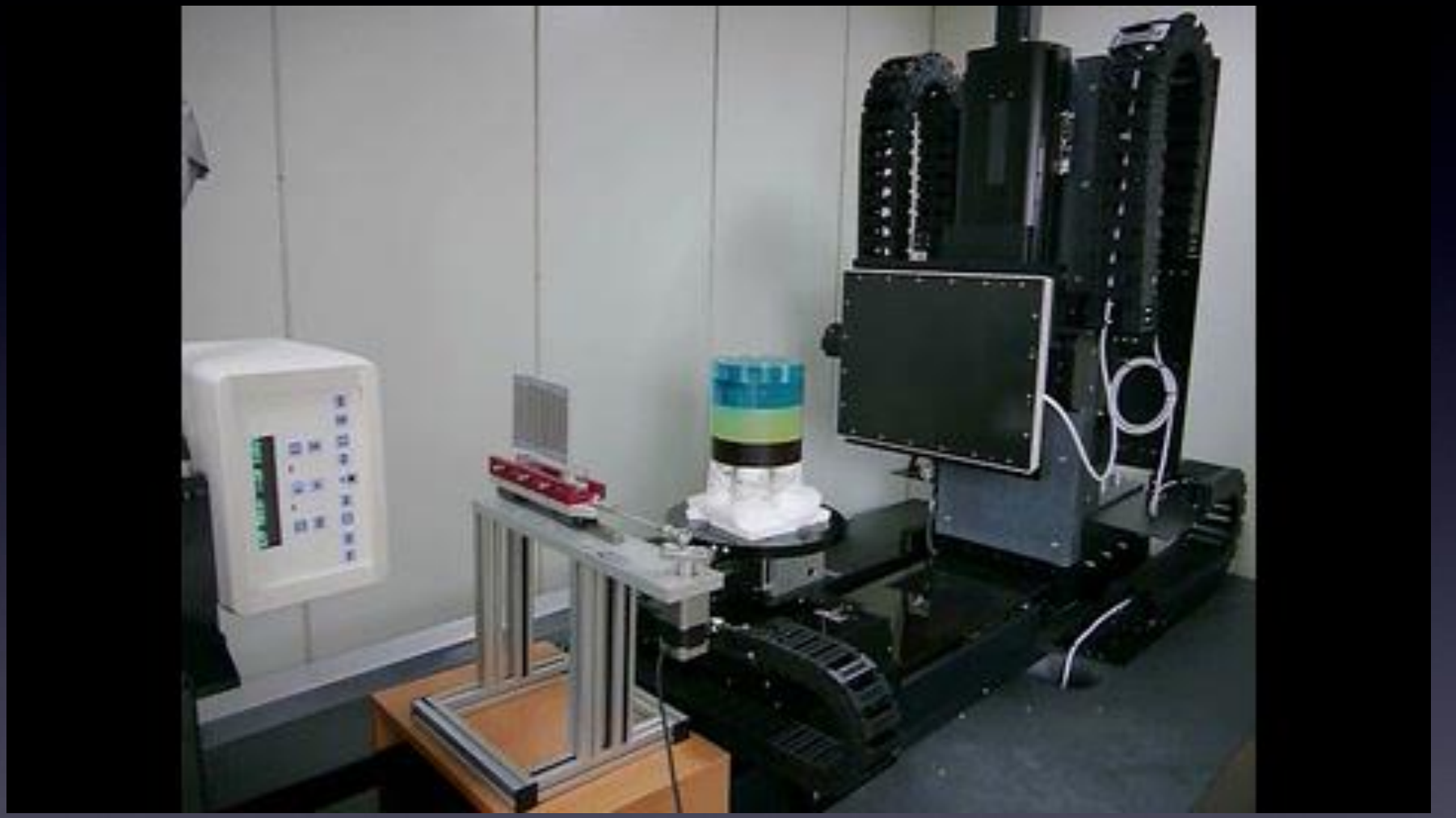
# Many-View Under-Sampling (MVUS)

- A multi-slit collimator is placed between source and object
- Oscillate it in a direction perpendicular to the rotation axis during a scan

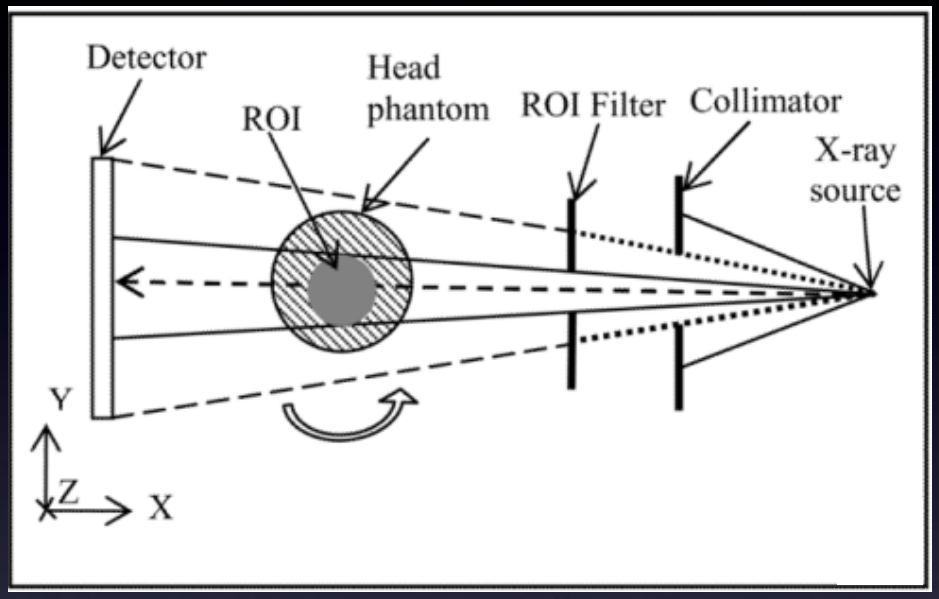




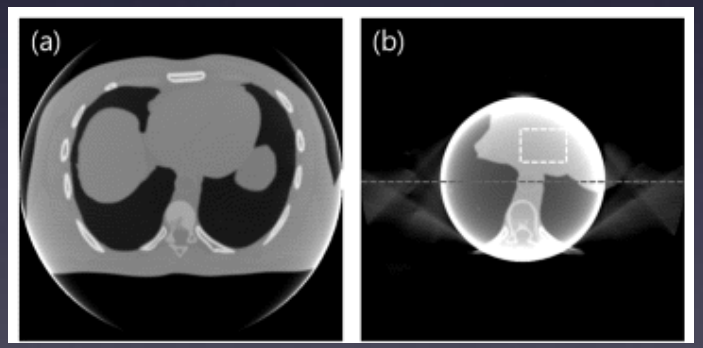

**(a) Full view (b) Sparse sampling (# of view : 90) / (c)Static collimator (iter : 160) / (d)MVUS (iter : 160)**



# ROI imaging



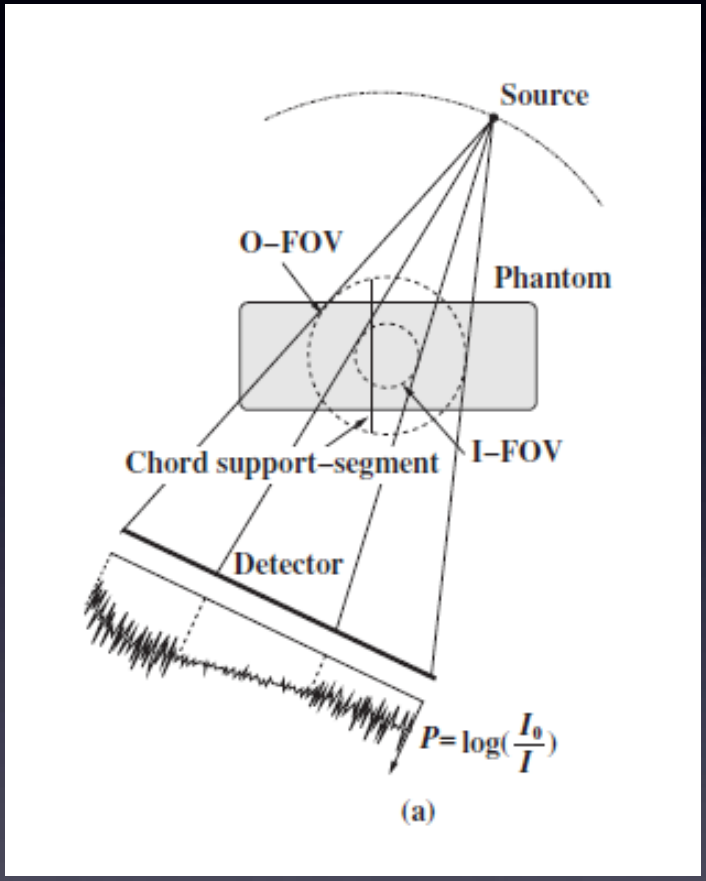

Schematic diagram of ROI CT imaging

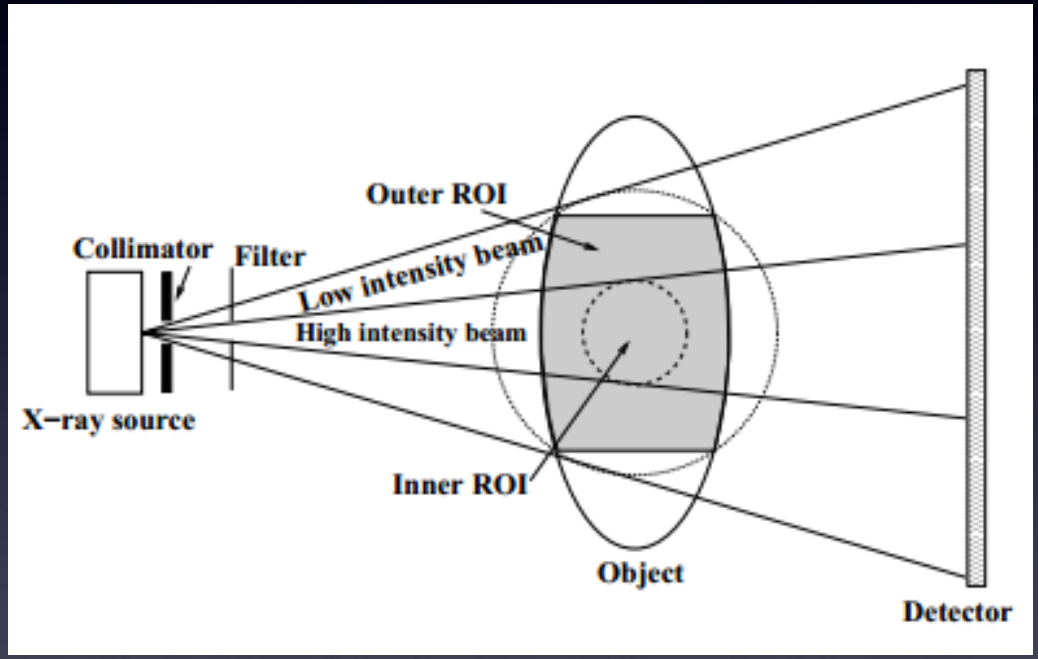



Reconstructed image of (a) Full view, (b) ROI

Region of interest computed tomography:
comparison with full field of view and truncated CT for human head phantom (2005)
Improving image accuracy of region-of-interest in cone-beam CT using prior image(2013)

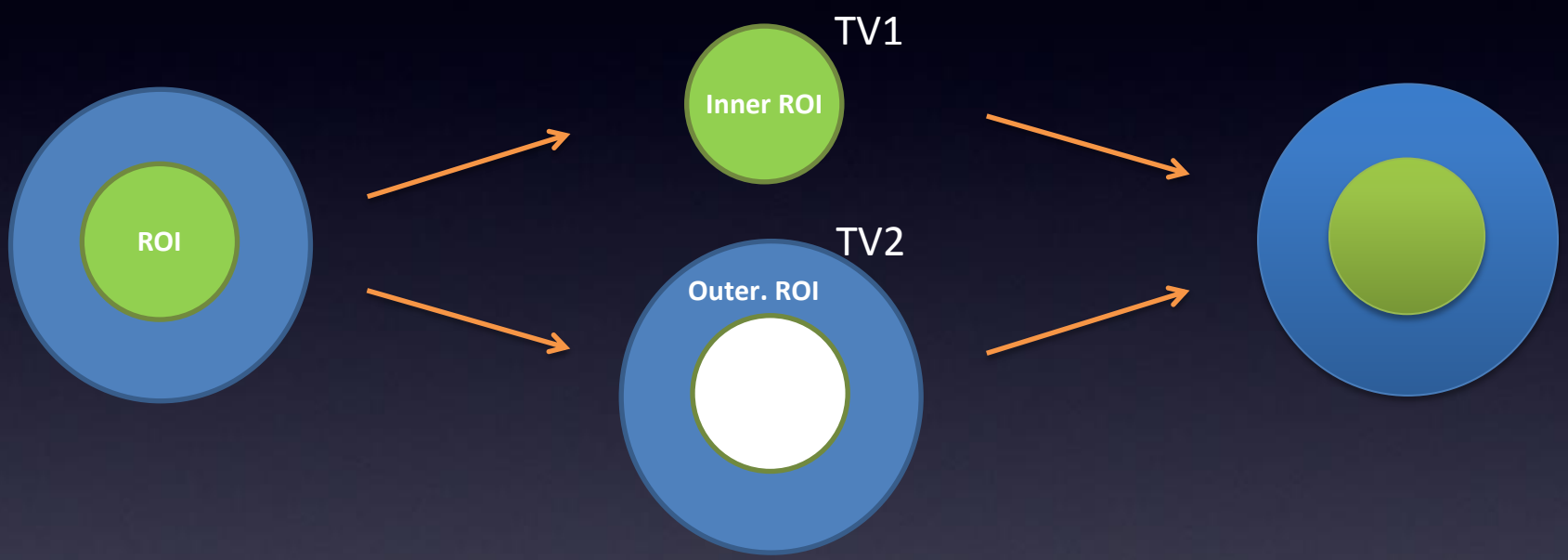
# Intensity Weighted ROI




A preliminary study of intensity-weighted ROI imaging in cone-beam CT

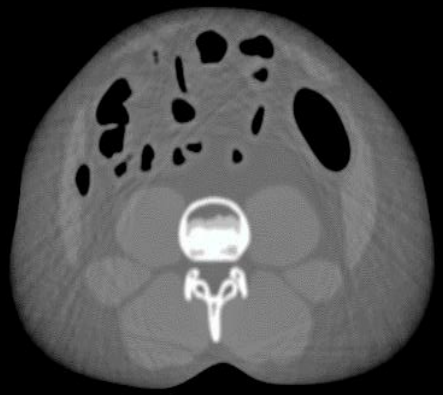
# Locally variant Weighted TV




ROI imaging

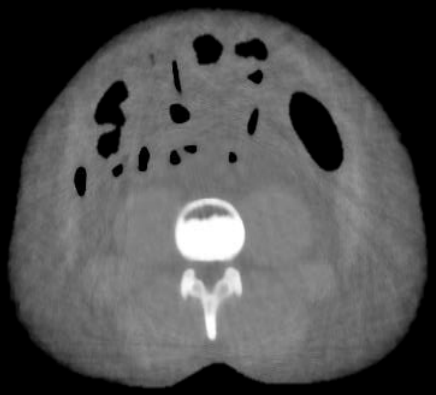
Locally variant Weighted TV

Recon. Imaging

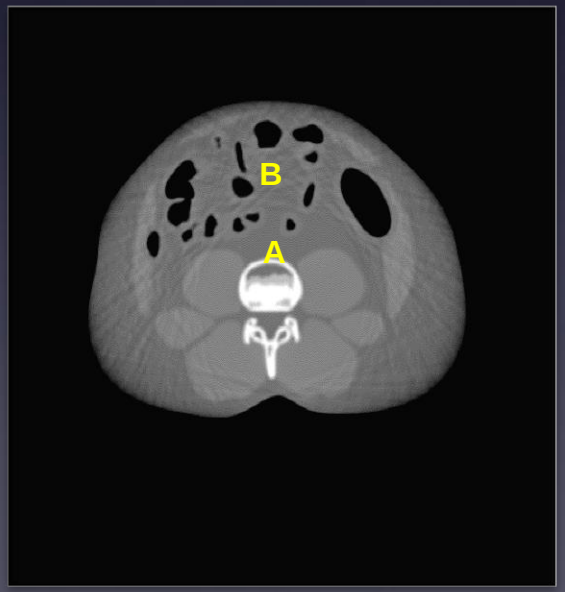


FDK 600

TV 120



LoTV 120



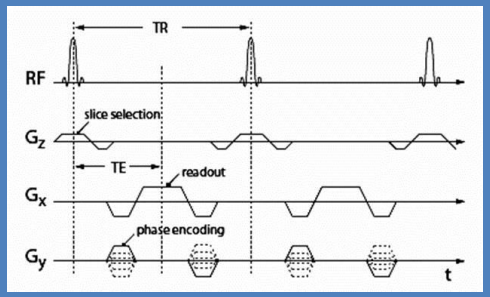

| Noise Levels | | | |
|---|---|---|---|
| | *FDK-600* | *TV-120* | *LoTV-120* |
| *A* | 5.67E-05 | 1.77E-04 > | **1.01E-04** |
| *B* | 1.71E-04 | 3.51E-04 > | **2.70E-04** |

# MRI

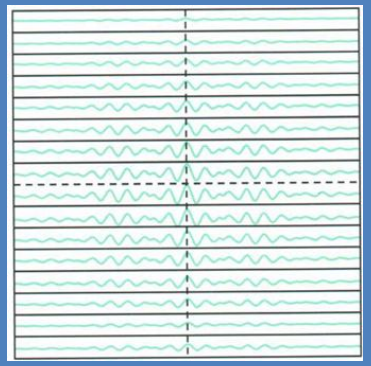
**Scan time reduction**

# How MRI obtains images?

MRI scanner

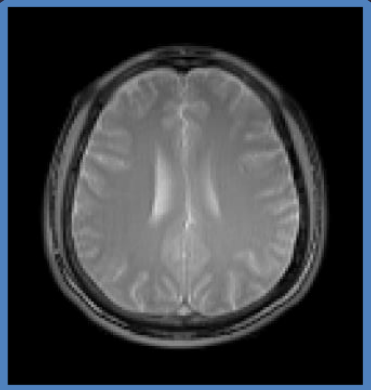



Pulse sequence



K-space

Fourier Transform



MR image

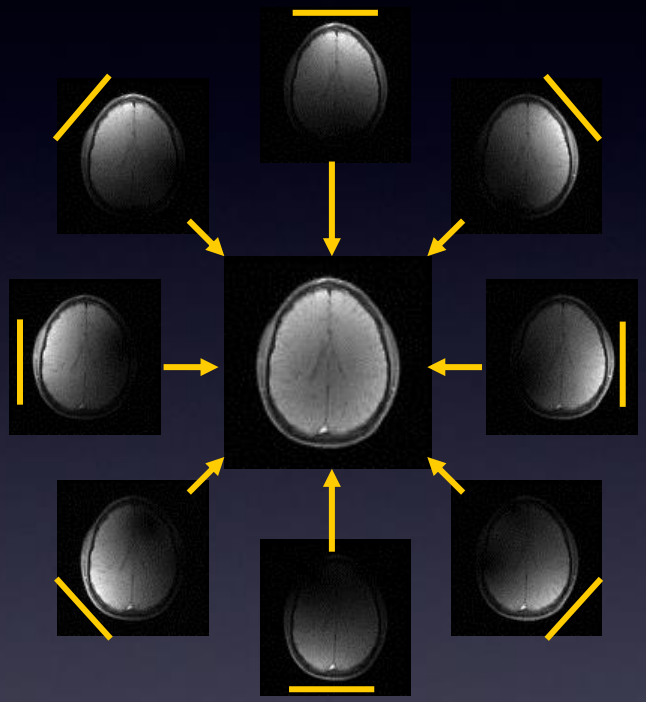
# Methods for reducing scan time

1. **Parallel Imaging** - Multi-coil information
2. **Compressed Sensing**
3. **Dual echo** - K-space reordering

# 1.parallel imaging

: Integrating multi-coil information

- k-space down sampling → SCAN TIME reduction



**SENSE** (Sensitivity Encoding)

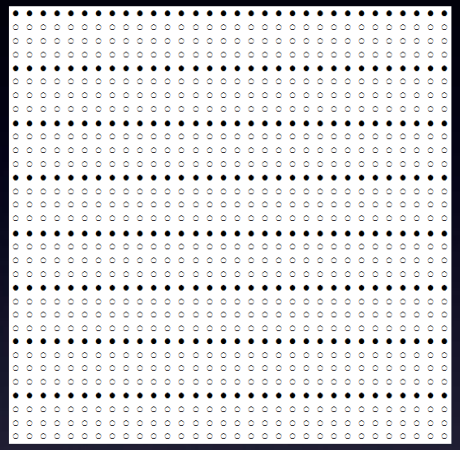
**GRAPPA** (GeneRalized Autocalibrating Partially Parallel Acquisitions)


- Non-Cartesian Parallel Imaging based on the GRAPPA Method - Nicole Seiberlich
- Workshop on Novel Reconstruction Strategies in NMR and MRI 2010

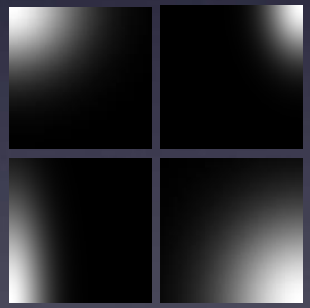
# 1.(1)SENSE (Sensitivity Encoding)

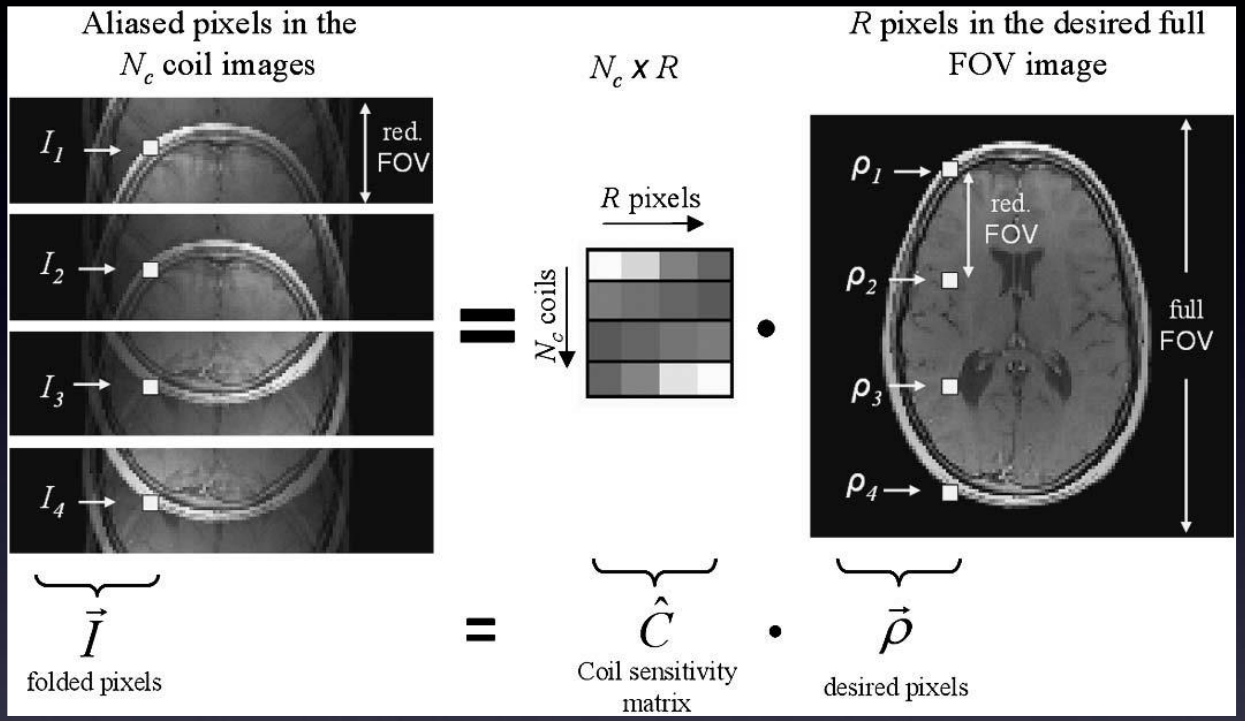
: process on image

**Down-sampled k-space (1/4)**



**Sensitivity matrix** $C$





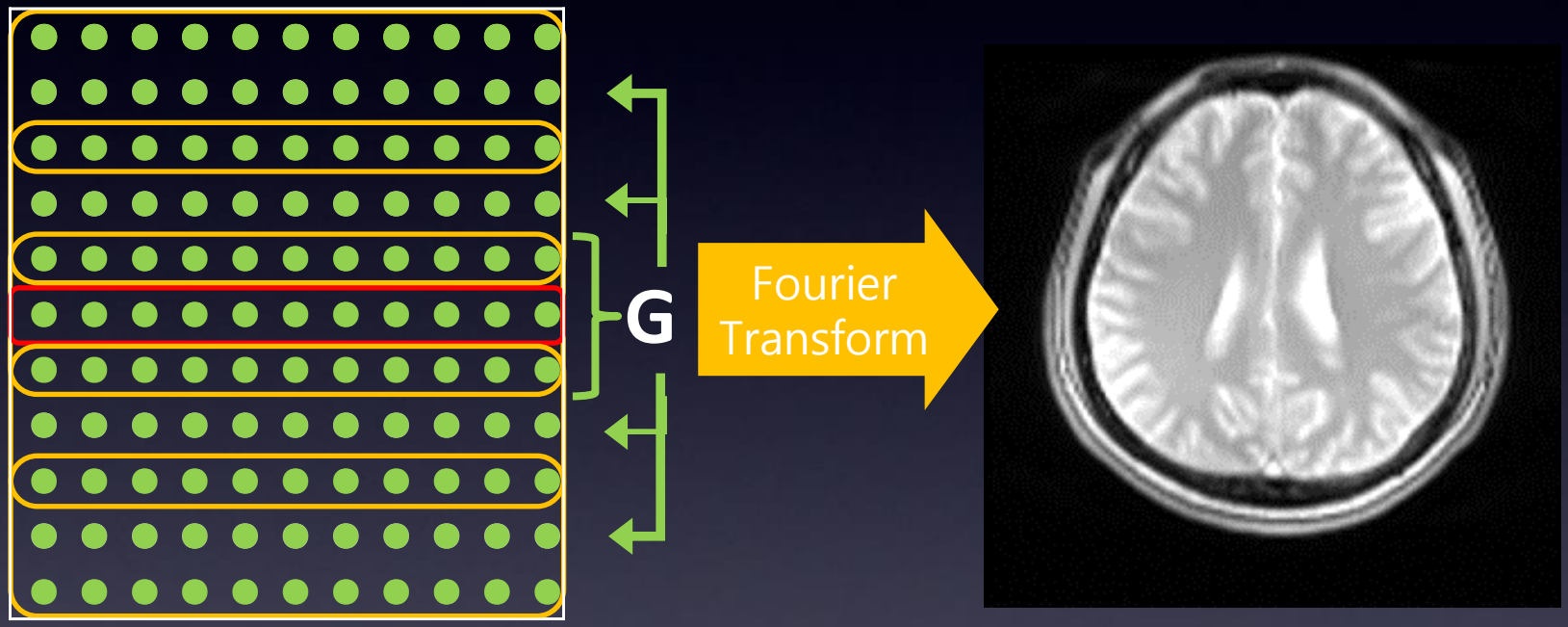

$$\vec{\rho} = (\hat{C}^H \hat{C})^{-1} \hat{C}^H \cdot \vec{I}$$

SMASH, SENSE, PILS, GRAPPA - *How to Choose the Optimal Method,* Top Magn Reson Imaging, Blaimer (2004)

# 1.(2) GRAPPA

: process on k-space

- **Assumption** : linear combination between k-space lines
- No need to acquire coil-sensitivity

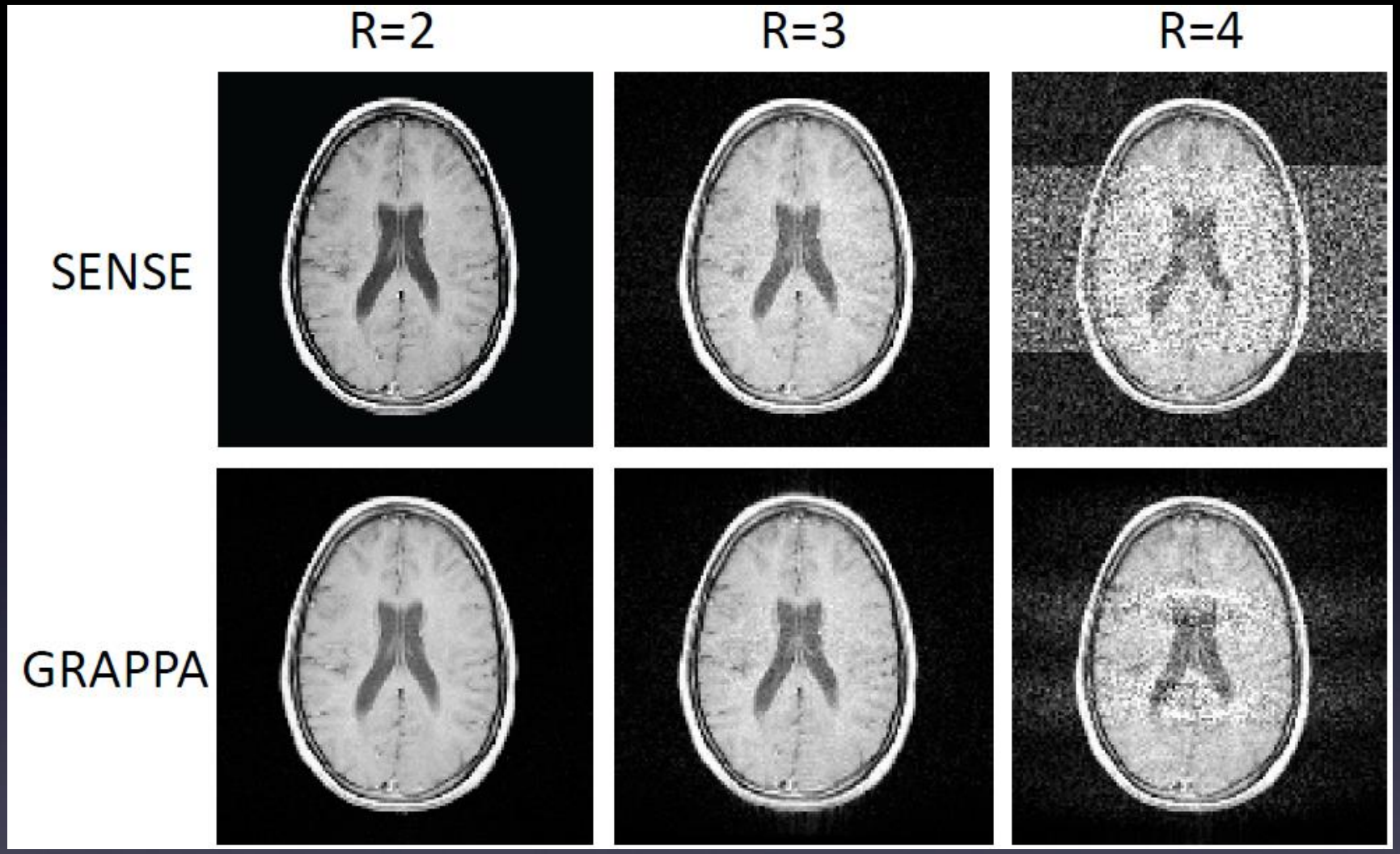



**y=Gx**

x : k-space data

G : GRAPPA kernel

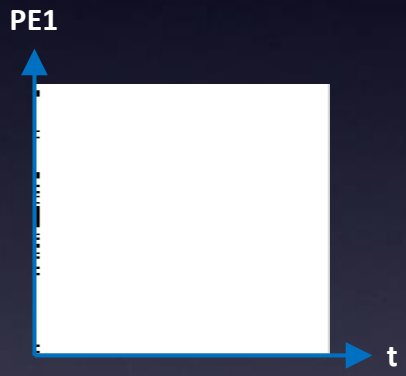
SMASH, SENSE, PILS, GRAPPA - *How to Choose the Optimal Method,* Top Magn Reson Imaging, Blaimer (2004)

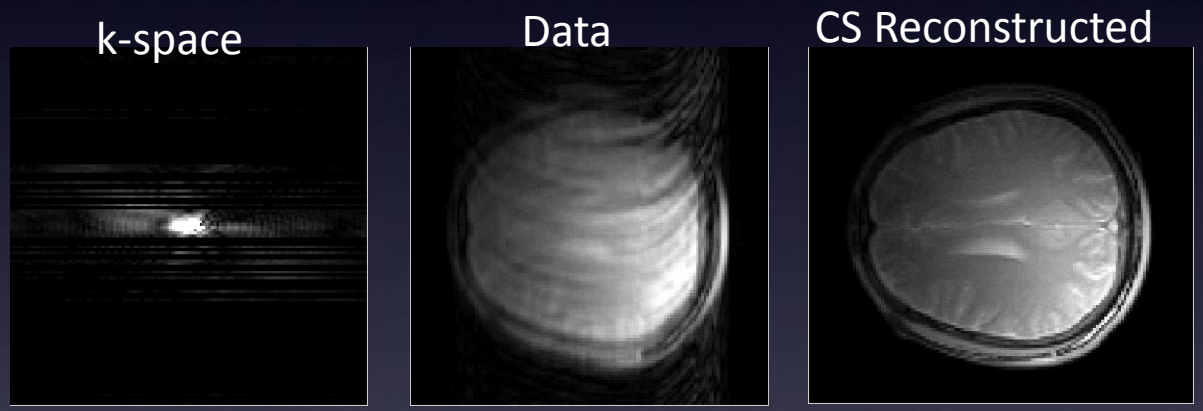

R=2
R=3
R=4
SENSE
GRAPPA

# 2. Compressed sensing

: Original image can be reconstructed by taking only few measurement

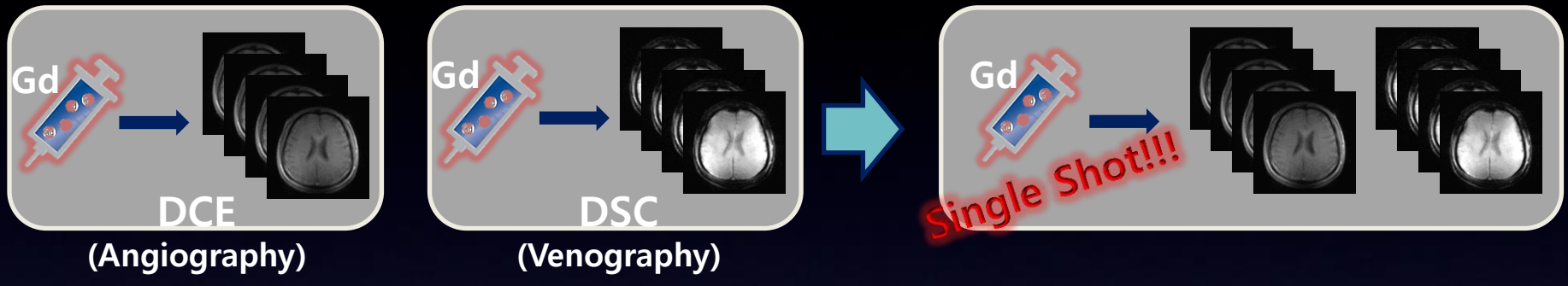
- Good for sparse data reconstruction
- Exploits temporal redundancy for reconstruction of information

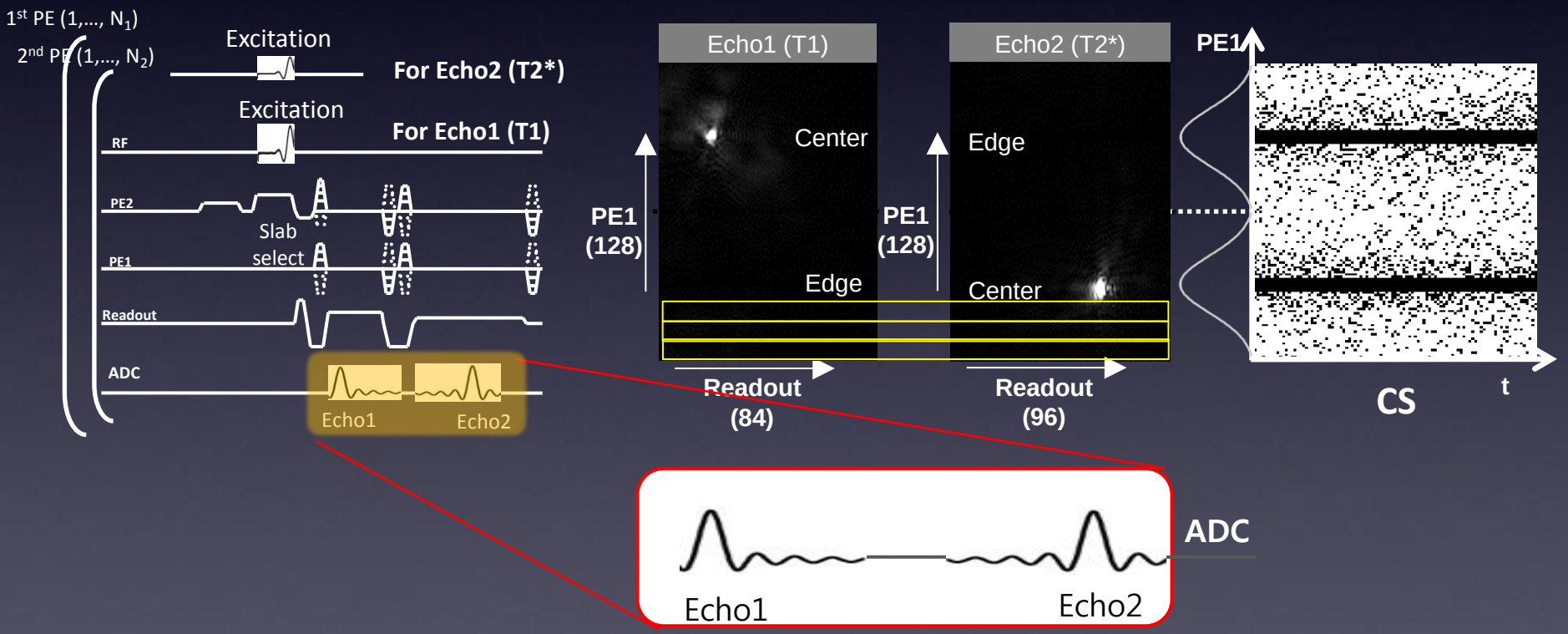


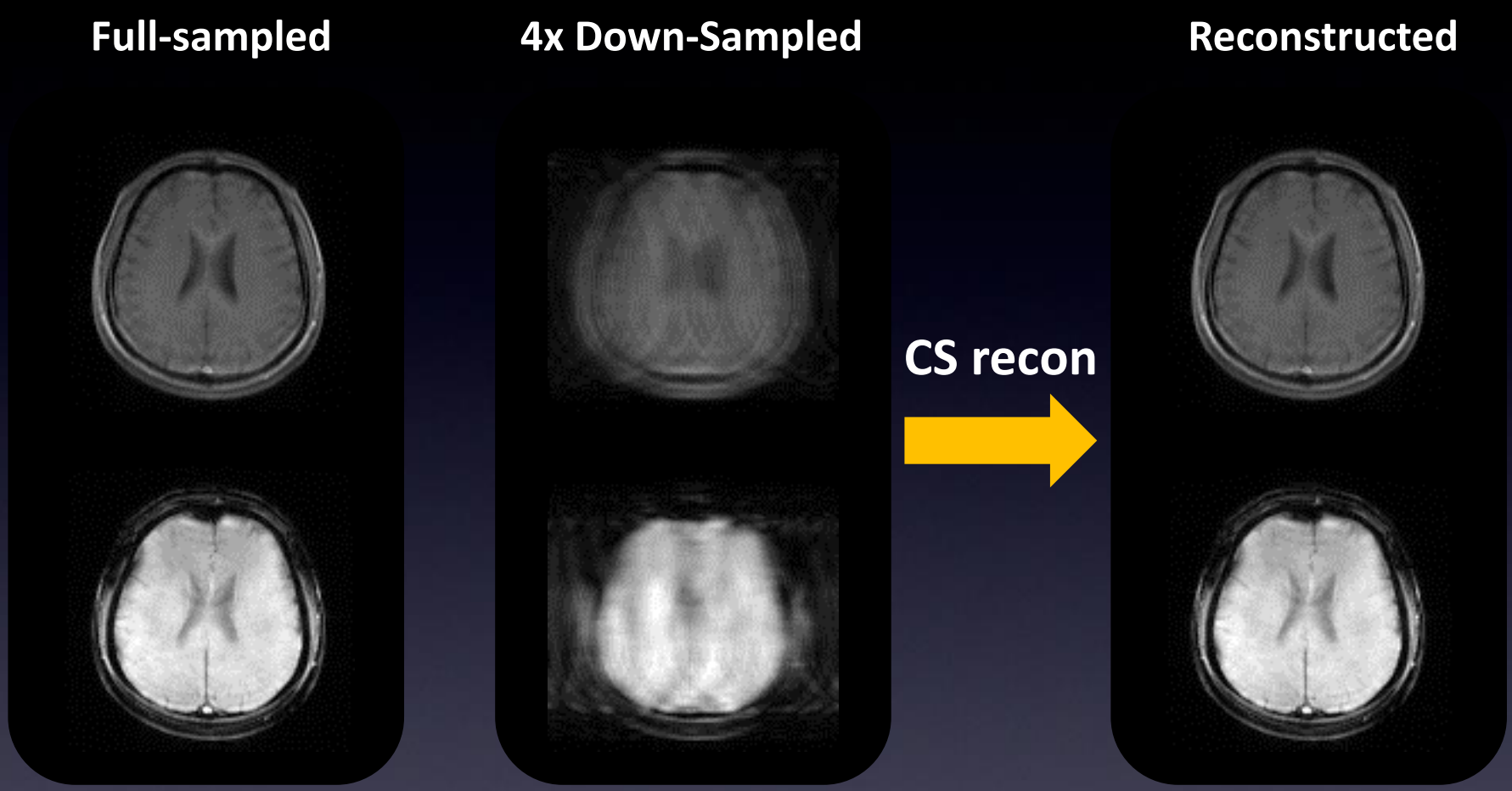



# 3. Dual echo

: k-space reordering






- Good reconstruction quality
- Structural detail and contrast are preserved

Thank you!!