

# EMORe: Motion-robust XD-CMR reconstruction using Expectation-Maximization (EM) algorithm

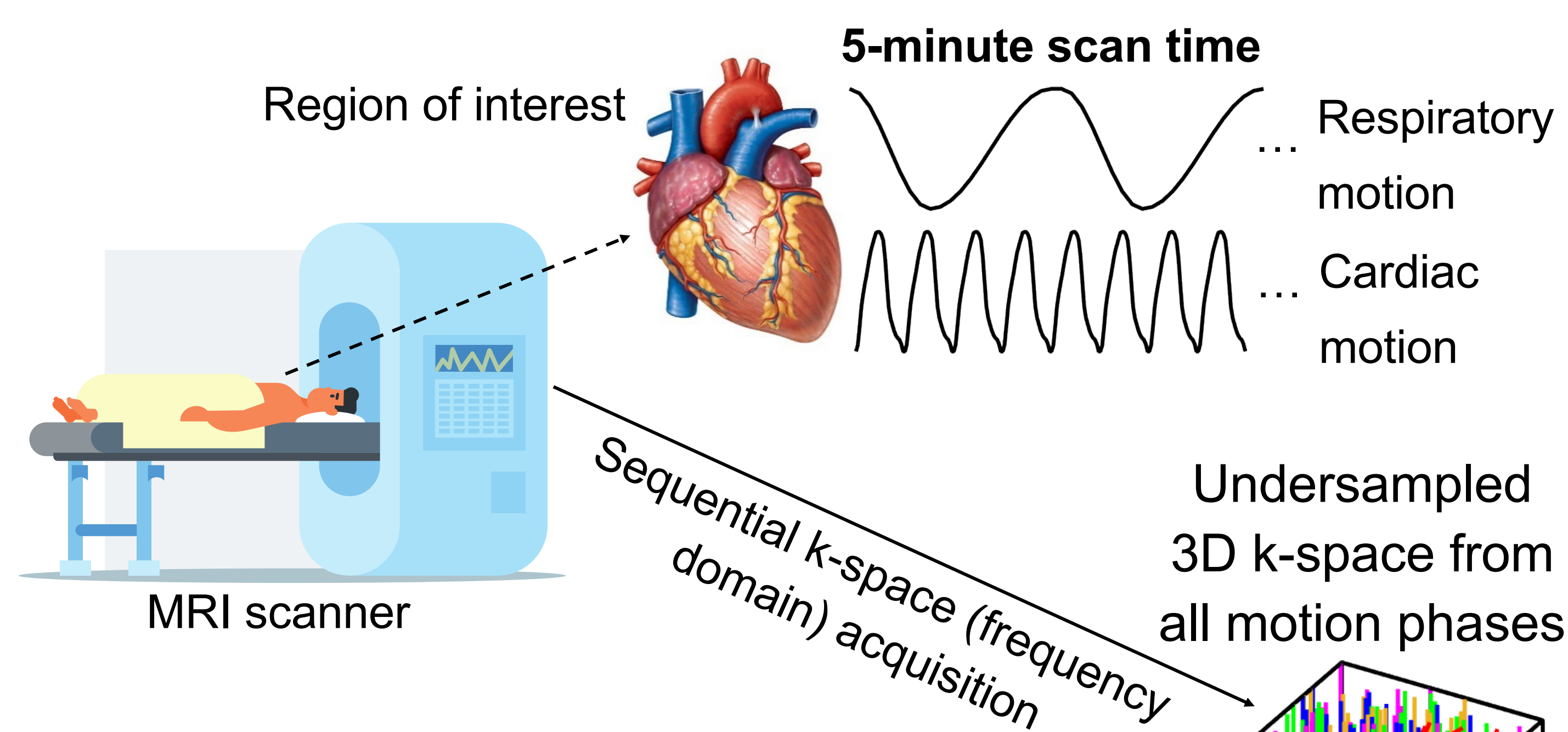
Syed Murtaza Arshad (Arshad.32@osu.edu), Lee Potter, Xuan Lei, Rizwan Ahmad

## INTRODUCTION

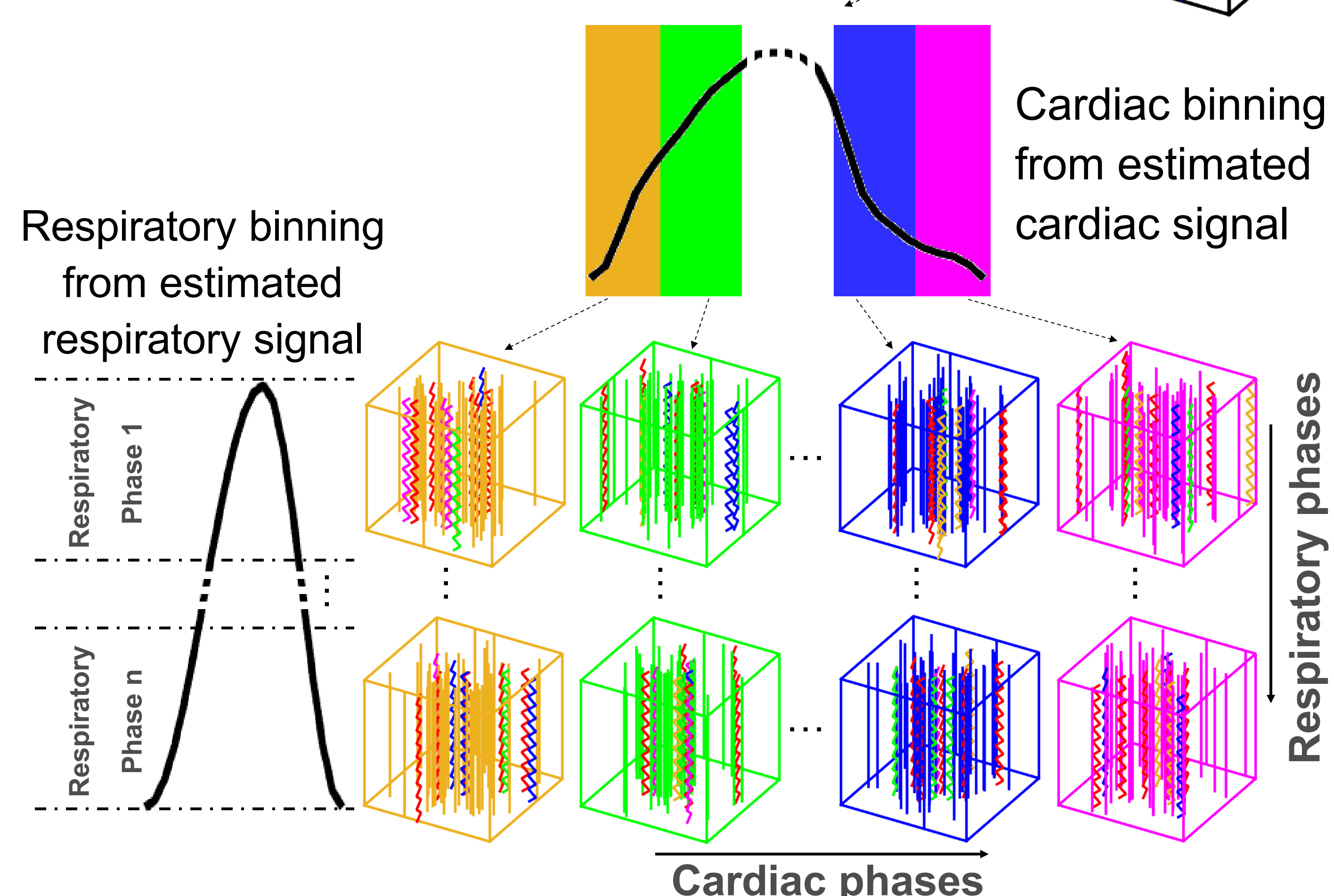
### XD-CMR

- Extra dimension-cardiac magnetic resonance imaging (XD-CMR) combines 3D imaging of **whole-heart** with cardiac and respiratory phase effects.
- Provides comprehensive assessment of cardiovascular structure and function in a **single acquisition**.

### Step I: XD CMR acquisition



### Step II: Acquired k-space data binning

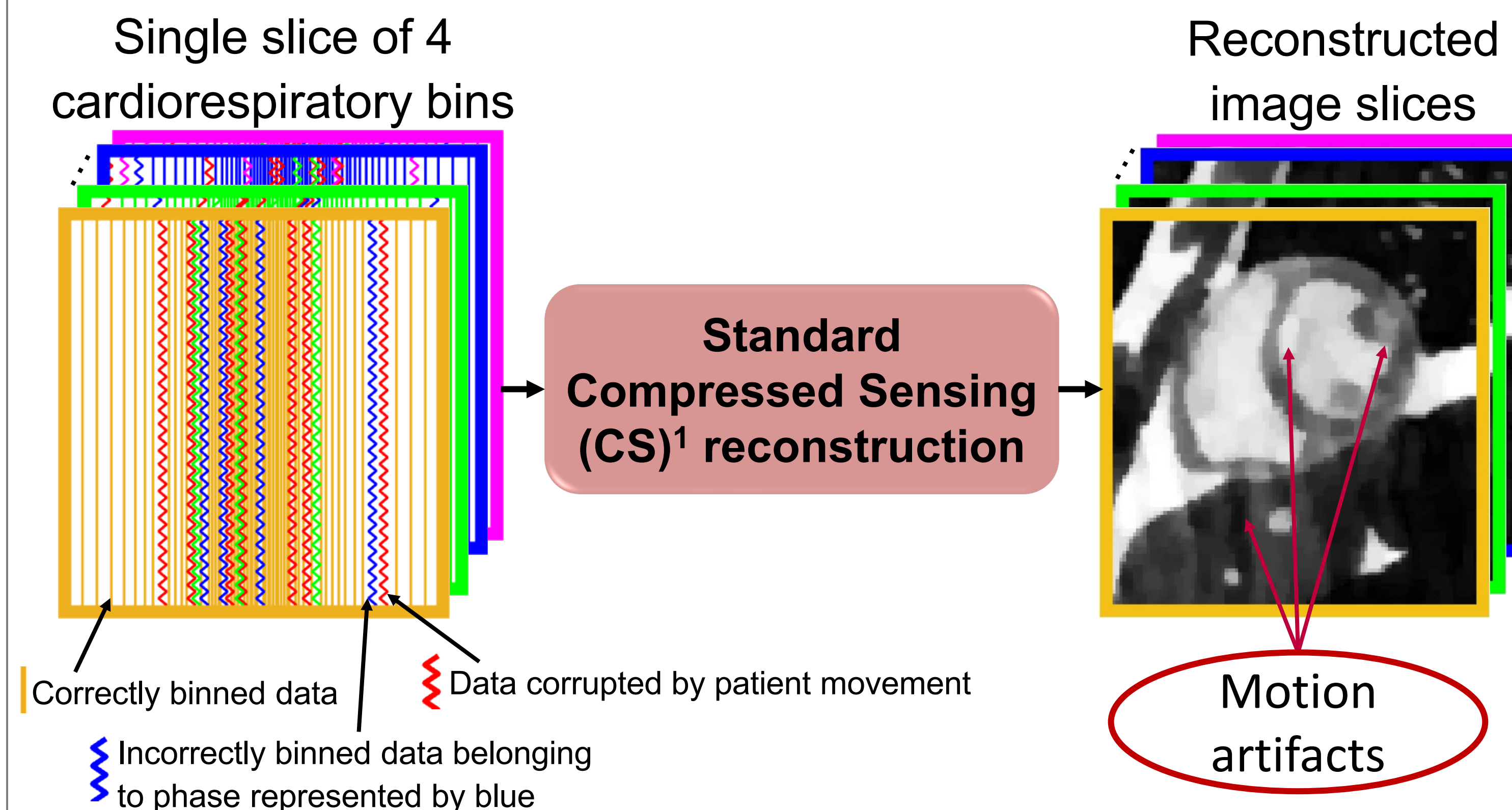


Correctly binned k-space data according to motion state

Incorrectly binned k-space data according to motion state

k-space data corrupted by exaggerated patient motion

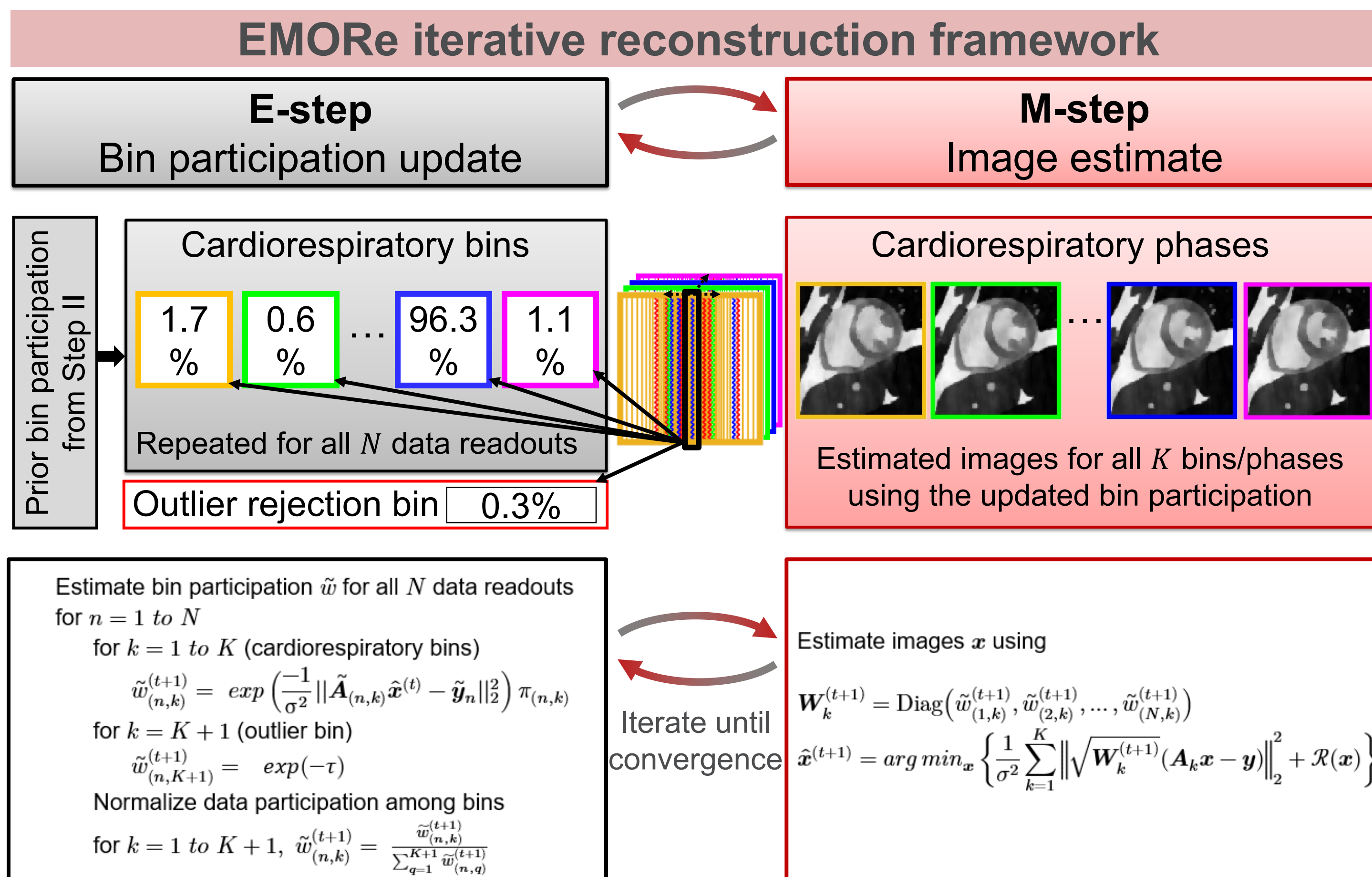
### Step III: Image reconstruction from binned k-space data



### Challenges of using standard reconstruction:

- Requires accurate **motion compensation** for both cardiac and respiratory motion
- Cardiac and respiratory **motion estimation** using blind-source-separation techniques is **not perfect**
- Incorrectly binned data leads to **motion artifacts**
- Data corrupted by **exaggerated patient movement (outlier data)** causes **image blurring**

## PROPOSED METHOD



$t$  denotes the current iteration.

$N$  is the total number of data readouts.

$K$  is the total number of cardiorespiratory bins.

$\tau$  is the outlier threshold.

$\tilde{y}_n$  is the  $n^{\text{th}}$  single data readout.

$y$  represents vectorized  $N$  data readouts.

$\pi_{(n,k)}$  is the prior participation weight of  $n^{\text{th}}$  data readout to  $k^{\text{th}}$  cardiorespiratory bin.

$\hat{w}_{(n,k)}^{(t+1)}$  represents the updated participation weight of  $n^{\text{th}}$  readout to  $k^{\text{th}}$  bin, using EM.

$\tilde{A}_{(n,k)}$  represents mapping from  $k^{\text{th}}$  phase of image  $x$  to  $n^{\text{th}}$  data readout  $\tilde{y}_n$ .

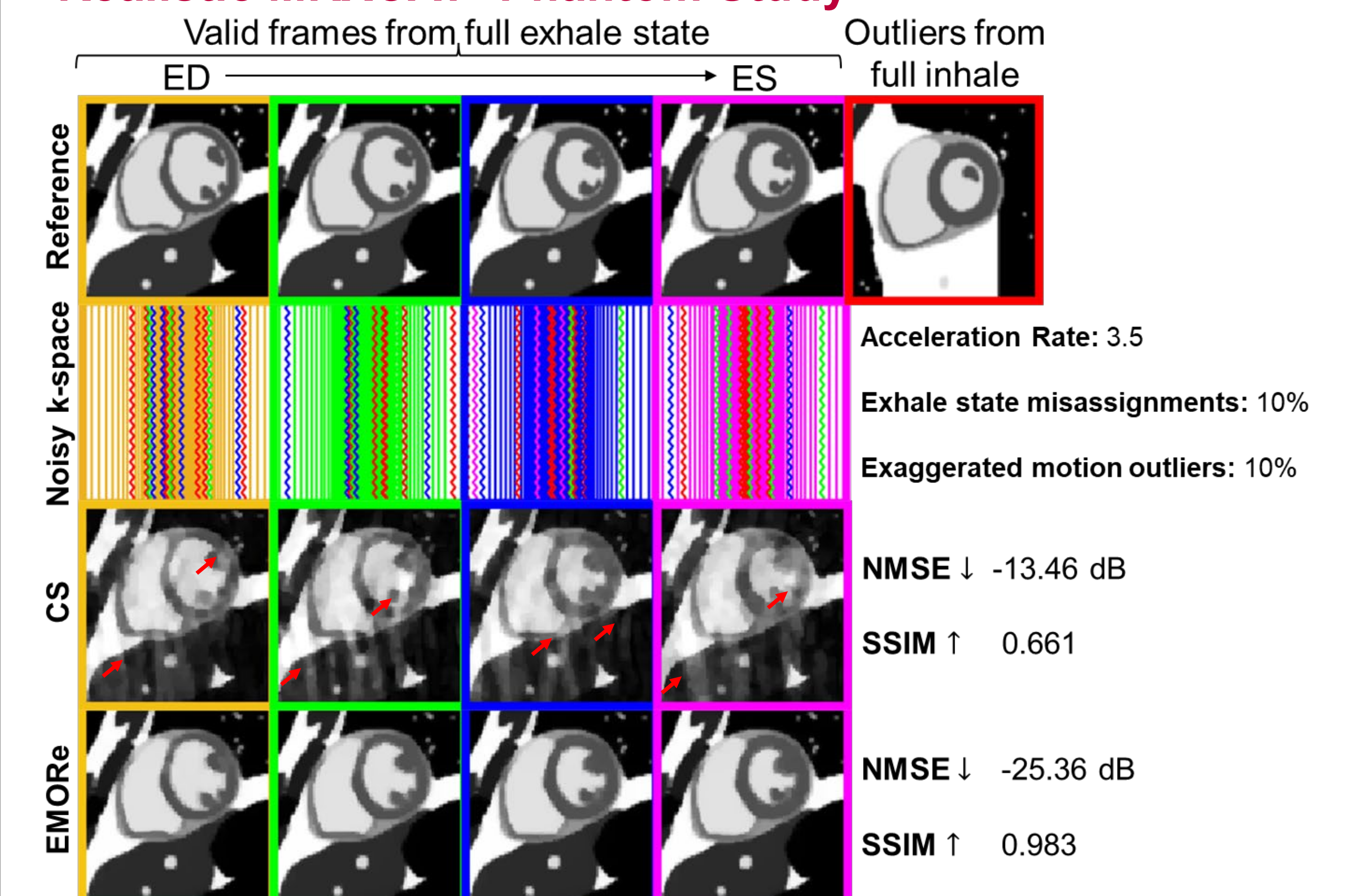
$\mathbf{A}_k$  represents mapping from  $k^{\text{th}}$  cardiorespiratory phase of image  $x$  to all readouts in  $y$ .

## EMORe: Expectation-Maximization (EM)-guided binning with Outlier Rejection

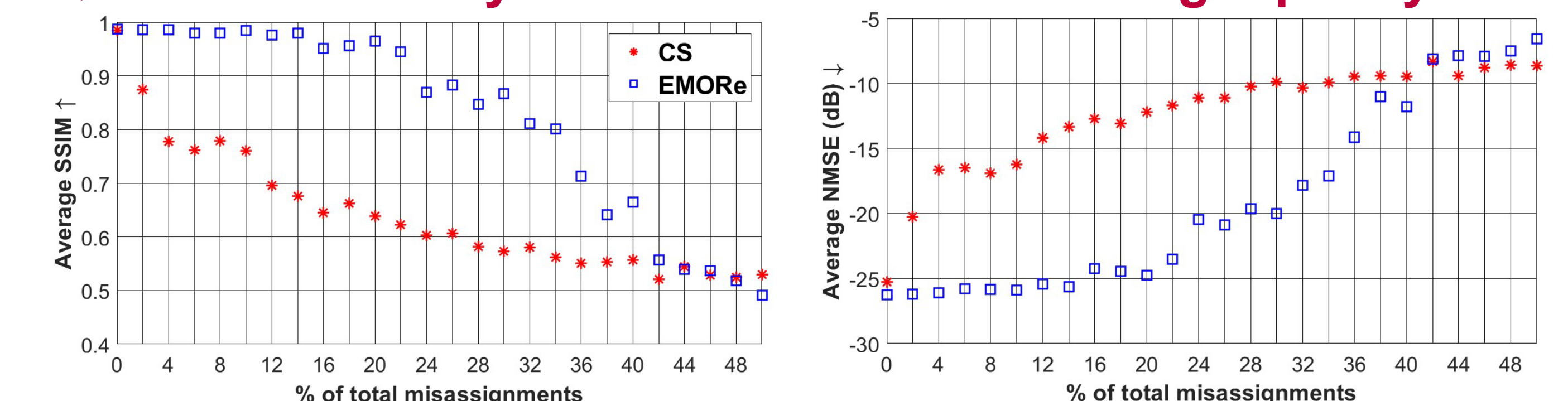
- Refines** the cardiorespiratory **bin participation** during reconstruction using the EM<sup>2</sup> algorithm.
- Integrates **outlier rejection** with EM, data corrupted by exaggerated motion are rejected to an extra outlier bin.
- Improves the image estimate** using the measured data and the refined bin participation, until convergence.

## RESULTS

### Realistic MRXCAT<sup>3</sup> Phantom Study



### Quantitative analysis of EMORe and CS image quality



## CONCLUSION

The proposed EMORe framework makes XD-CMR reconstruction more robust to motion, resulting in improved diagnostic-quality images. In future work, we will apply EMORe to reconstruct in vivo 5D flow data from patient studies.

## REFERENCES

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- McLachlan, G. J., & Krishnan, T. (2007). *The EM Algorithm and Extensions: Second Edition*. In *The EM Algorithm and Extensions: Second Edition*.
- Wissmann, L., Santelli, C., Segars, W. P., & Kozerke, S. (2014). MRXCAT: Realistic numerical phantoms for cardiovascular magnetic resonance. *Journal of Cardiovascular Magnetic Resonance*, 16(1).



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