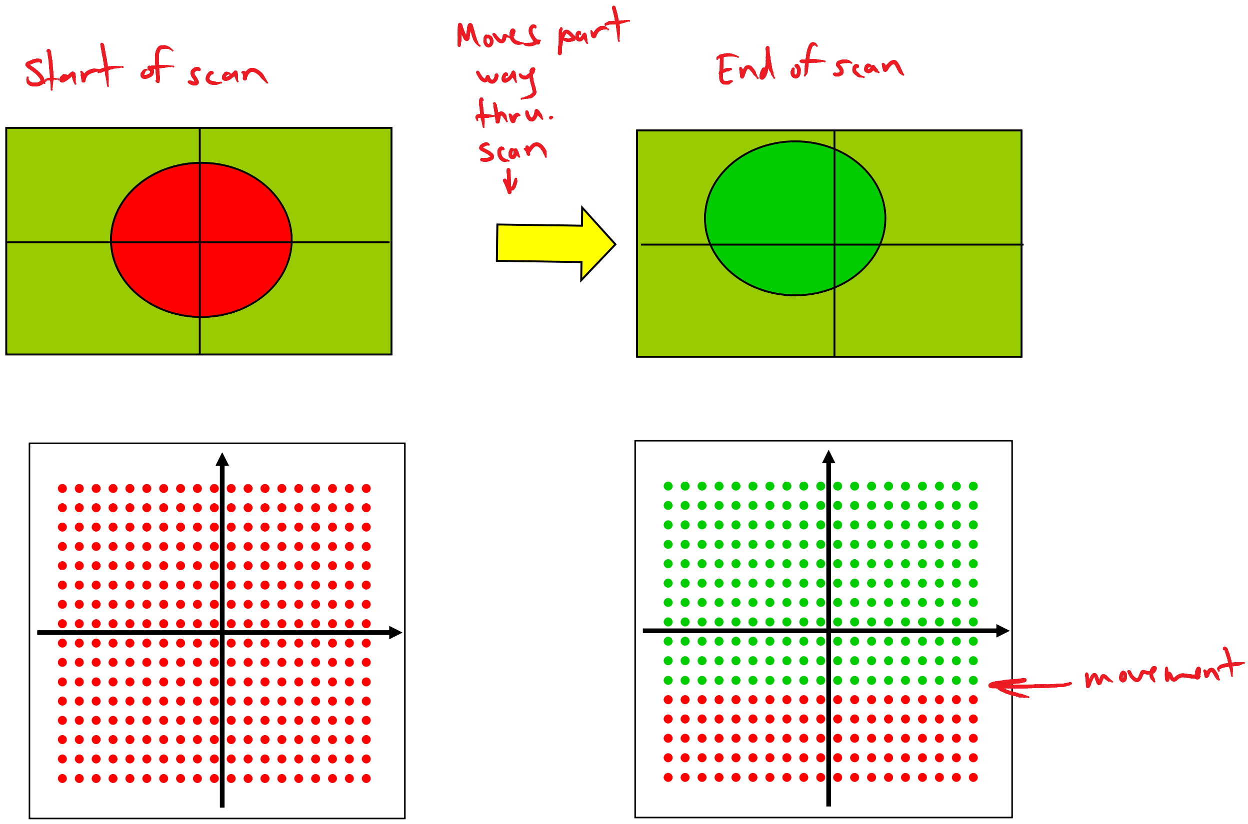
MRI Motion Compensation

L45

Goal: To investigate how patient motion can corrupt MR images, and some methods for correcting it.

The MR scanner collects the samples in *k*-space no matter what the patient does.

If the patient moves part way through the scan, the data collected will not be consistent, so will not reconstruct to the correct image. This motion that happens during the acquisition of a single image is called **intra-scan** motion.

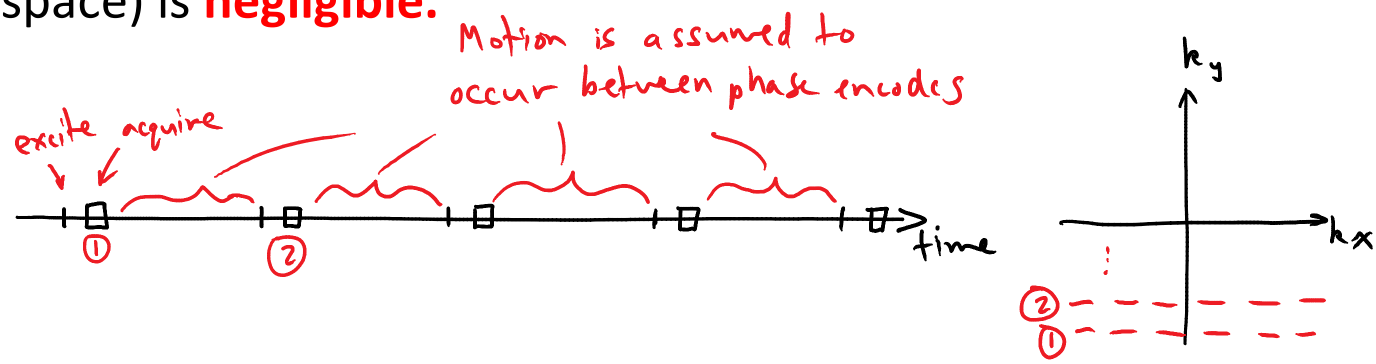


These inconsistencies cause **"motion artifacts"** in the reconstructed images.

Motion-free

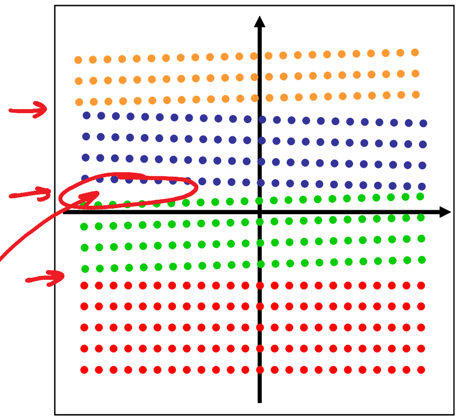
Motion-corrupted

Much of the effects of motion can be corrected by **post-processing.** Most methods assume that motion is **slow** enough that motion within a single "phase encode" (row in *k*-space) is **negligible.**



A translation in the patient causes the signal (the anatomy) to shift, which causes a phase ramp in its Fourier coefficients.
If you know the translation, you can undo it by simply changing the **phases** of the *k*-space samples using the appropriate **phase ramp.**

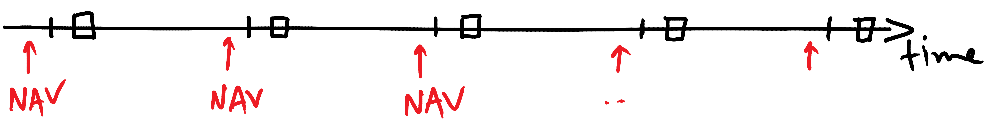
Rotation of the patient will **rotate** the corresponding content in the frequency domain.
If you know the rotations, you can compensate (to some extent) by **counter-rotating** the samples.



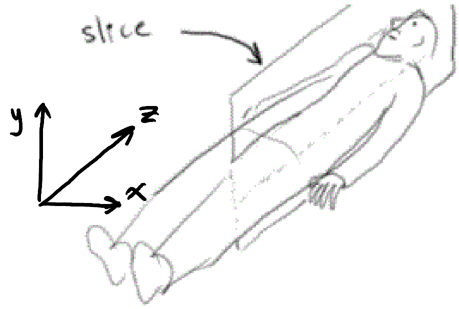
Information is lost if there are **under-sampled** regions.

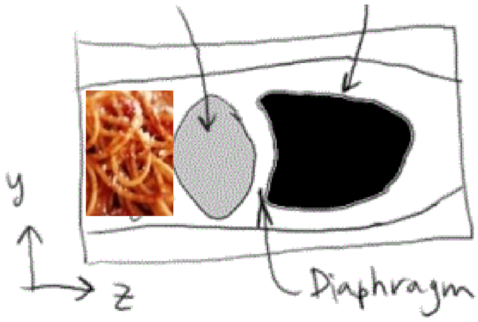
Navigator Echoes

Navigator echoes, or **NAVs,** are small sets of *k*-space samples that are acquired between imaging excitations. Their purpose is to gain an estimate of the patient's position. The echoes commonly consist of a few lines in *k*-space. These ultra-fast acquisitions are **interleaved** throughout the scanning sequence, and are useful in intra-scan motion correction because they offer a **repeated** set of measurements that can be used to **estimate position.**

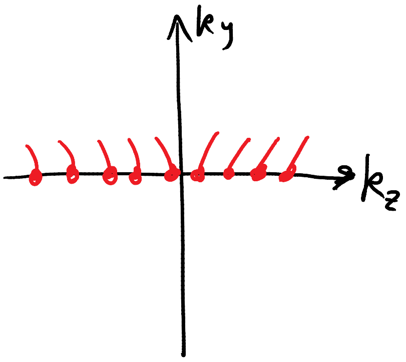


For these NAVs to be super-fase, naturally they are not full images.
Consider the saggital slice below.



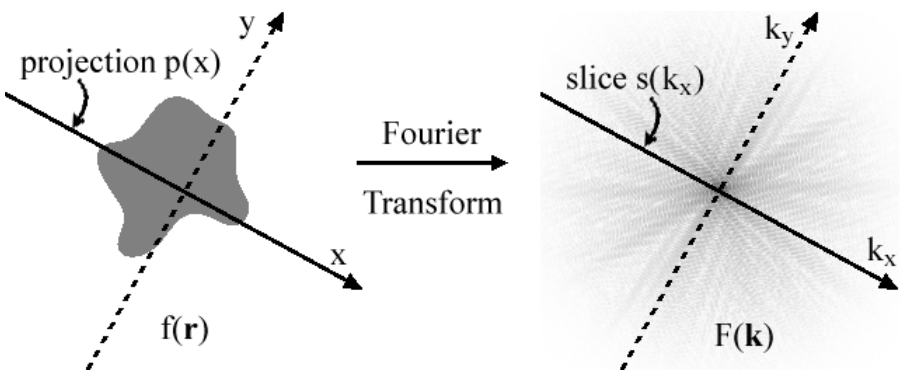


One could use all 3 gradients to acquire an image like above, but that would take too long (many excitation cycles). Instead, what would happen if, after exciting the slice, only the ***z*-gradient** was used for spatial encoding?
Ie. **No y-gradient was used.**



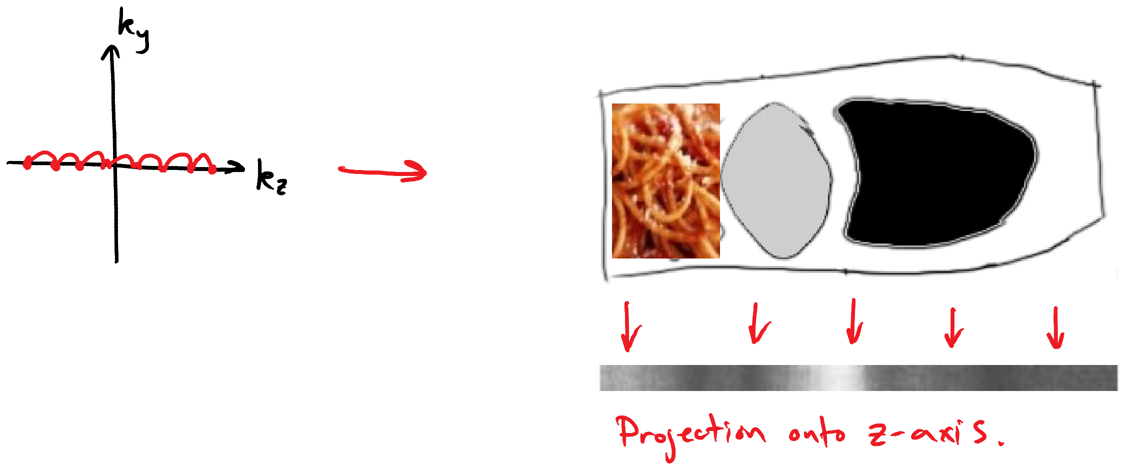
Performing the reconstruction (via a 1D IFFT), this gives a 1D signal.
What does it represent?
Hint: Unsampled coefs are all zeros.
What would the 2D IFFT give you?

Recall the Projection Slice Theorem:

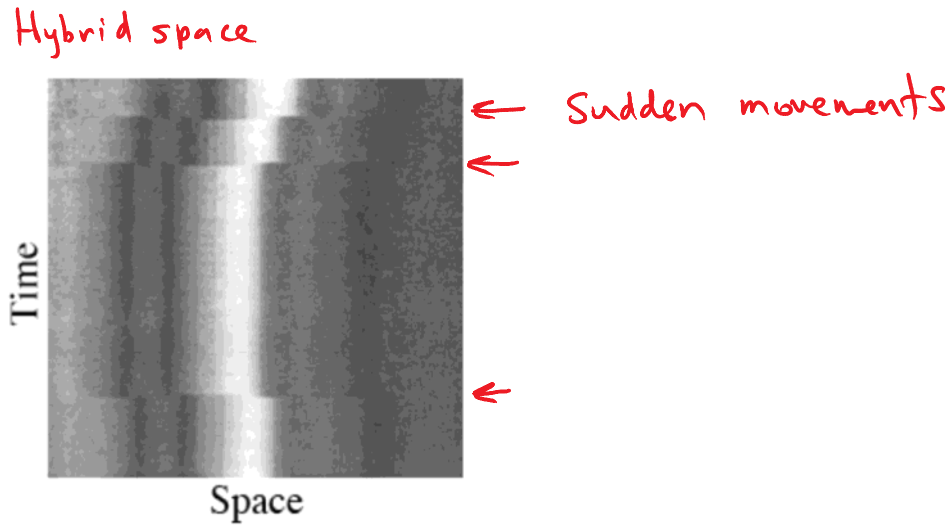


http://en.wikipedia.org/wiki/Projection-slice_theorem

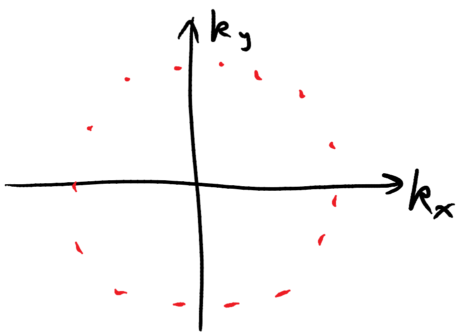
One line of *k*-space samples gives you a **projection** of the spatial-domain signal.



Collecting these projections during the scan can give use information about motion during the scan.



An **"orbital NAV"** collects a circle of samples in *k*-space, and allows one to determine both **translation and rotation.**



Entropy Focussing

If you do not know the patient motion, there are some methods to try to guess the motion.

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Automatic Correction of Motion Artifacts in Magnetic Resonance Images Using an Entropy Focus Criterion

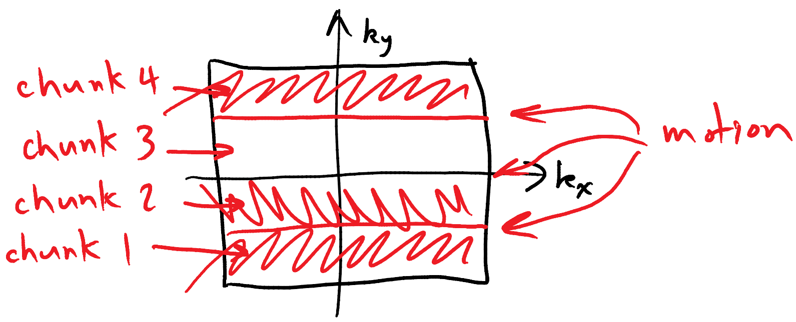
David Atkinson, Derek L. G. Hill,* *Member, IEEE*, Peter N. R. Stoyle, Paul E. Summers, and Stephen F. Keevil

This approach is based on the fact that most movements cause ghost-like artefacts to appear in the background and dark parts of the image. These additional structures tend to **increase** the **entropy** of the image.

If we assume the motion is fairly slow, we can use a multi-resolution approach in time.

Here is the idea:

1) Group phase encodes into **chronological** chunks, and assume motion only occurs between these chunks.

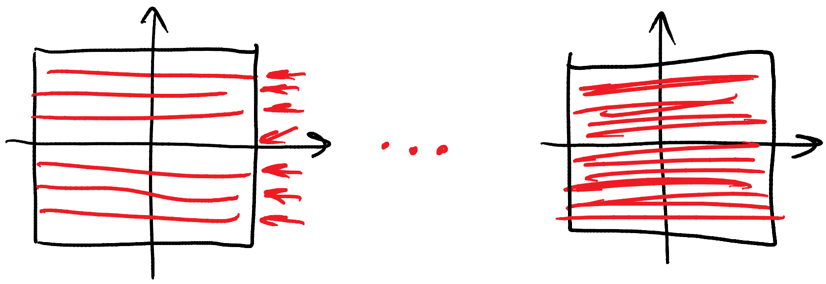


2) Choose motion parameters, and apply the corresponding correction to the each chunk.
3) Reconstruct the image (IFFT).
4) Compute the **entropy** of the reconstructed image.
5) Adjust the motion parameters to reduce the image **entropy.**

Optimization: minimize the image **entropy** by iterating the steps above.

Once it's done, subdivide the temporal chunks into smaller chunks and repeat the optimization.

More motion parameters, but probably smaller motions.



The translation corrections can be applied using Fourier Shift Theorem, and rotation corrections are implemented by rotating the *k*-space samples.
Note that the original *k*-space data is already in the **frequency** domain, so these corrections are being applied to the raw samples.