# Spiral Projection Imaging: a new fast 3D trajectory

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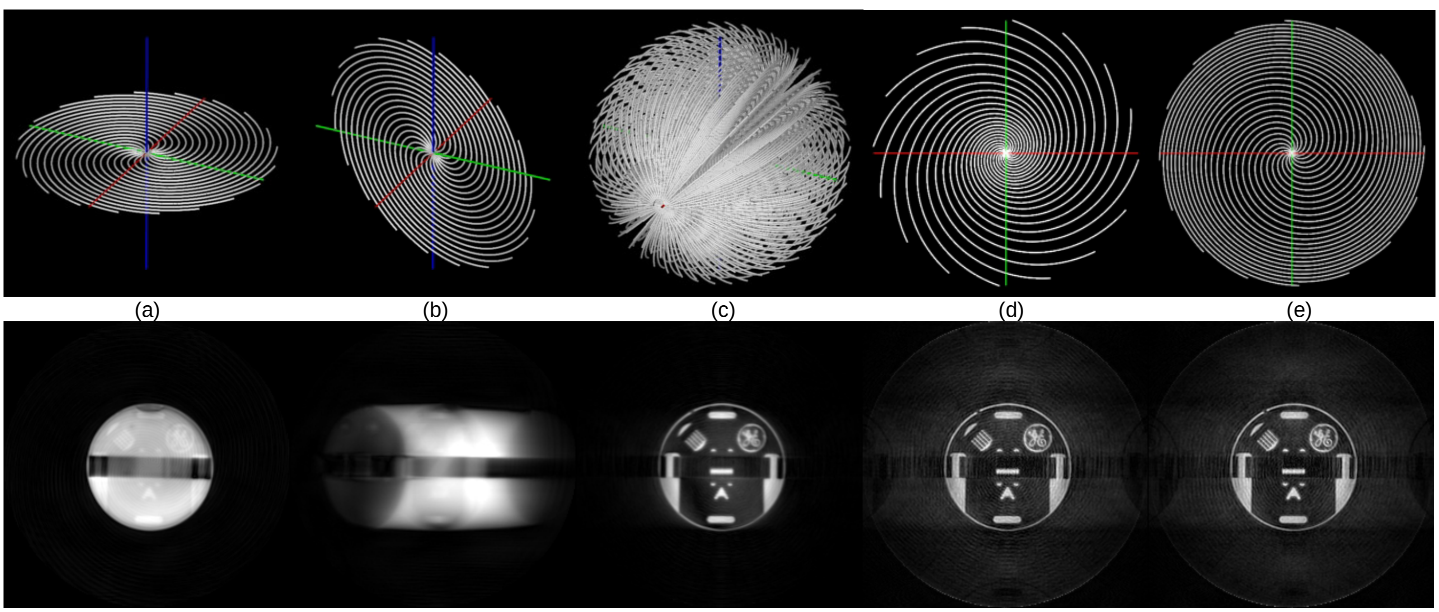
**Introduction:** A new 3D k-space trajectory, called "Spiral Projection Imaging", is proposed. It is obtained by taking a complete 2D set of spiral trajectories in (e.g.) $\{k_x, k_y\}$ space (a "spiral plane", Fig. 1a), and rotating them about (e.g.) the $k_x$ axis (Fig. 1b), until the set of spiral planes fills a sphere in k-space (Fig. 1c): This trajectory has the following properties:

1. It is a very fast method for filling 3D k-space, due to the spiral trajectory.
2. This method can be made much faster by undersampling, both radially in every spiral plane (Fig. 1d)[1], and azimuthally by reducing the number of planes, as with undersampled projection reconstruction.[2]
3. Because it is a radial technique, artifacts (including aliasing) tend to be less coherent than Cartesian methods.
4. Reconstruction can be done via 2D gridding along each spiral plane ($k_x$-$k_{y:z}$), then transforming along $k_x$, and then for each location x, performing a 2D polar gridding operation on the data in ($k_y$-$k_z$). This separable gridding (2 x 2D) is much faster computationally than that achieved with 3D.
5. If one rotates every other plane by (180˚/ # of interleafs), the data are hexagonally sampled in the ($k_y$-$k_z$) plane, reducing aliasing artifacts when undersampling (Fig 1. j (hard to see, but present)).
6. With the hexagonal sampling in #5 and the azimuthal oversampling about the $k_x$ axis from the spiral plane rotation, one can undersample the inner region of each spiral plane (Fig. 1e), speeding up data acquisition, without overall aliasing.
7. Because the data are oversampled in the center of k-space, one can collect the spiral planes in such a way to collect time-resolved data with a sliding-window approach, or reject bad data where it is uncorrelated with the rest.
8. Each spiral plane can be used to estimate rigid-body translation in 2 directions and rotation about 1 axis. Judicious ordering of the spiral planes allows rapid estimation of 2 directions of rotation and all 3 directions of translation.
9. The blurring due to spiral acquisition is isotropic, and rapid deblurring using an extension of ref. [3] is being investigated.

**Methods**: Spiral Projection Imaging was implemented on a GE 1.5T Excite with Echo-Speed Plus gradients, for a 24cm FOV and 1mm resolution. Data were 4X undersampled at the edges of the spiral both radially (Fig. 1d), and azimuthally. Projection images from spiral planes rotated by 0˚ and 45˚ about the $k_x$ axis are shown in Fig. 1f,g. Final images were reconstructed to minimize aliasing artifact (Fig. 1h) or maximize resolution (Fig 1j), as discussed in ref [4]. Reconstruction for these data sets took approximately 20 seconds on a 3Ghz P4 using C++ routines written in-house.



(a) (b) (c) (d) (e)
(f) (g) (h) (i) (j)

*Figure 1; (a) Spiral planes are rotated (b) to form the complete proposed trajectory (c). Spiral trajectories may be undersampled at the edges (d) or center (e) of k-space for time reduction. The projections from each plane (f,g) can then be used to form images which are weighted to reduce artifact (h) or increase resolution. Odd-plane shifting (see text) mitigates aliasing artifacts (j).*

**References**: 1. Mag Res Med 43(3), 452. 2. Mag Res Med 43(1), 91. 3. Mag Res Med 44(3), 491. 4. Mag Res Med 43(6), 867.

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