Journée thématique calculs/simulations

Magnetic Resonance Imaging (IRM)

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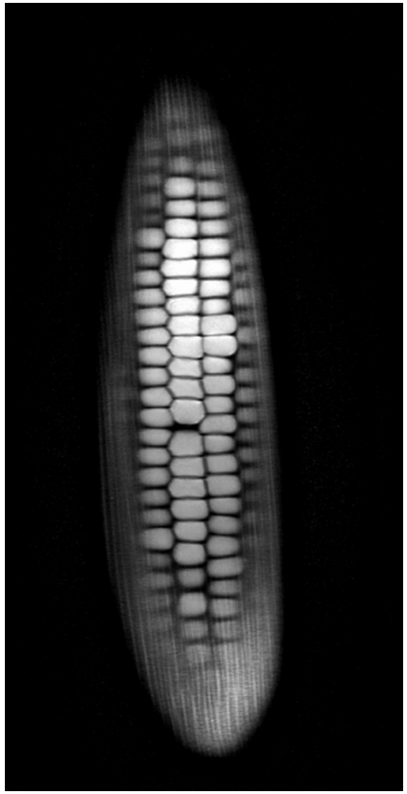
Introduction

a) Magnetic resonance imaging (MRI)

- No invasive, no ionizing, 1D, 2D and 3D imaging technic of complex objects
- Based on magnetic resonance phenomenum
- Main part of the applications: imaging of ^{1}H of water
- The contrast are obtained by proton density difference or tissues rigidity difference

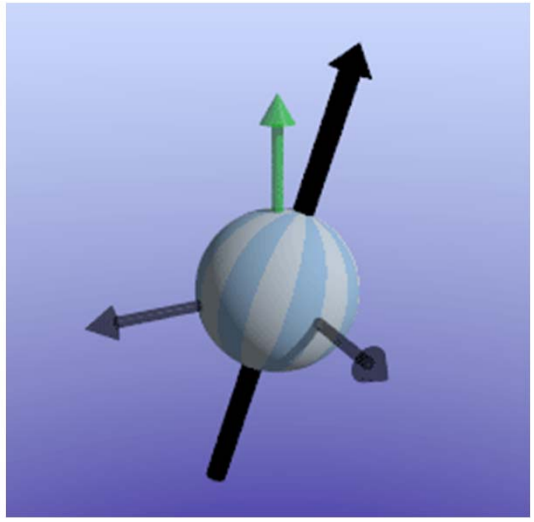


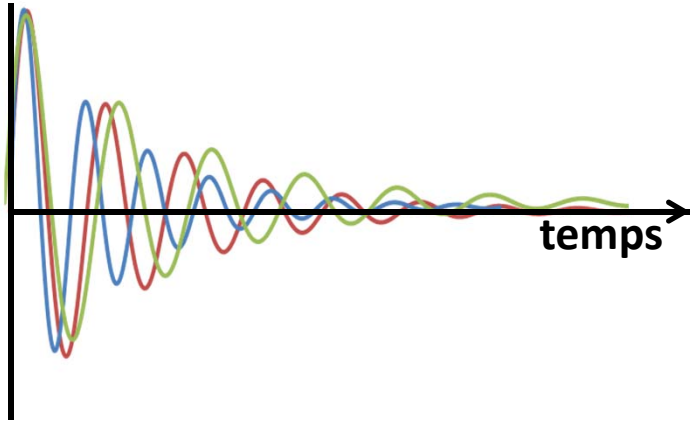
^{1}H MRI of water molecules of a corn cob by Andy Ellison

I) Principle

a) Magnetic resonance

- Immerse in an intense magnetic field the magnetic moment of the nucleus: the spin rotate along the magnetic field
- This magnetic component in rotation can be detect by induction in a coil placed around the object
- This gives the nuclear magnetic resonance signal: the FID (Free Induction Decay)

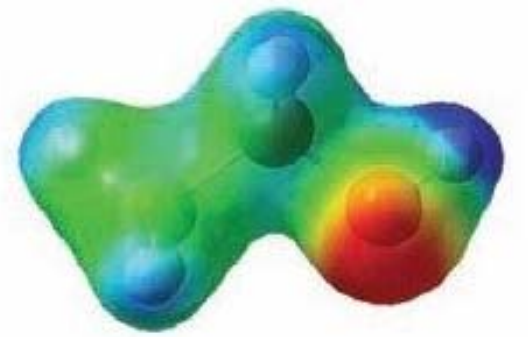


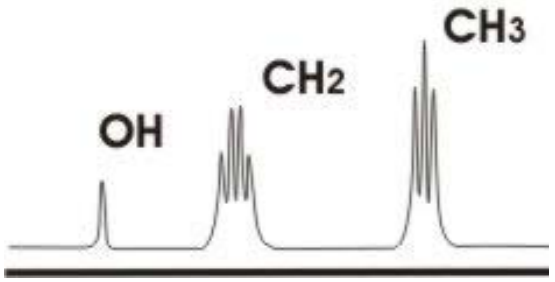


I) Principle

b) NMR spectroscopy

- The spin resonance frequency depends of the magnetic field
- The nucleus are shielded by the electron density
- The electron density is modified by the chemical environment
- **Thus the resonance frequency depends of the chemical environment**
- The Fourier transform of the signal give the NMR spectrum

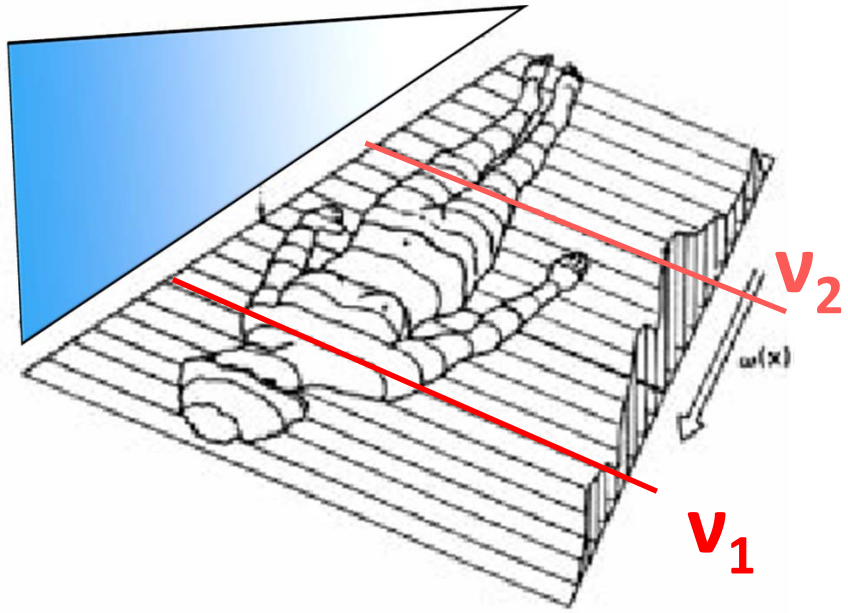




I) Principle

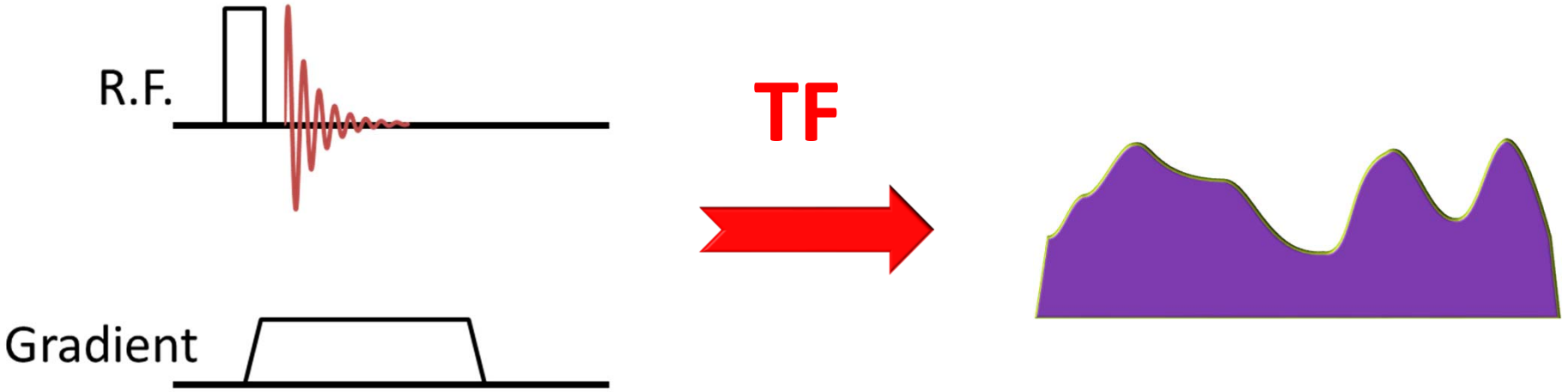
c) Magnetic Resonance Imaging (MRI)

- The spin resonance frequency depends of the magnetic field
- With the addition of a magnetic field gradient**: the spin resonance frequency depends of the spin spatial position** along the gradient
- The signal of the whole object is acquired and the Fourier transform give the 1D image (profile) of the spin density of the object



II) Spatial encoding

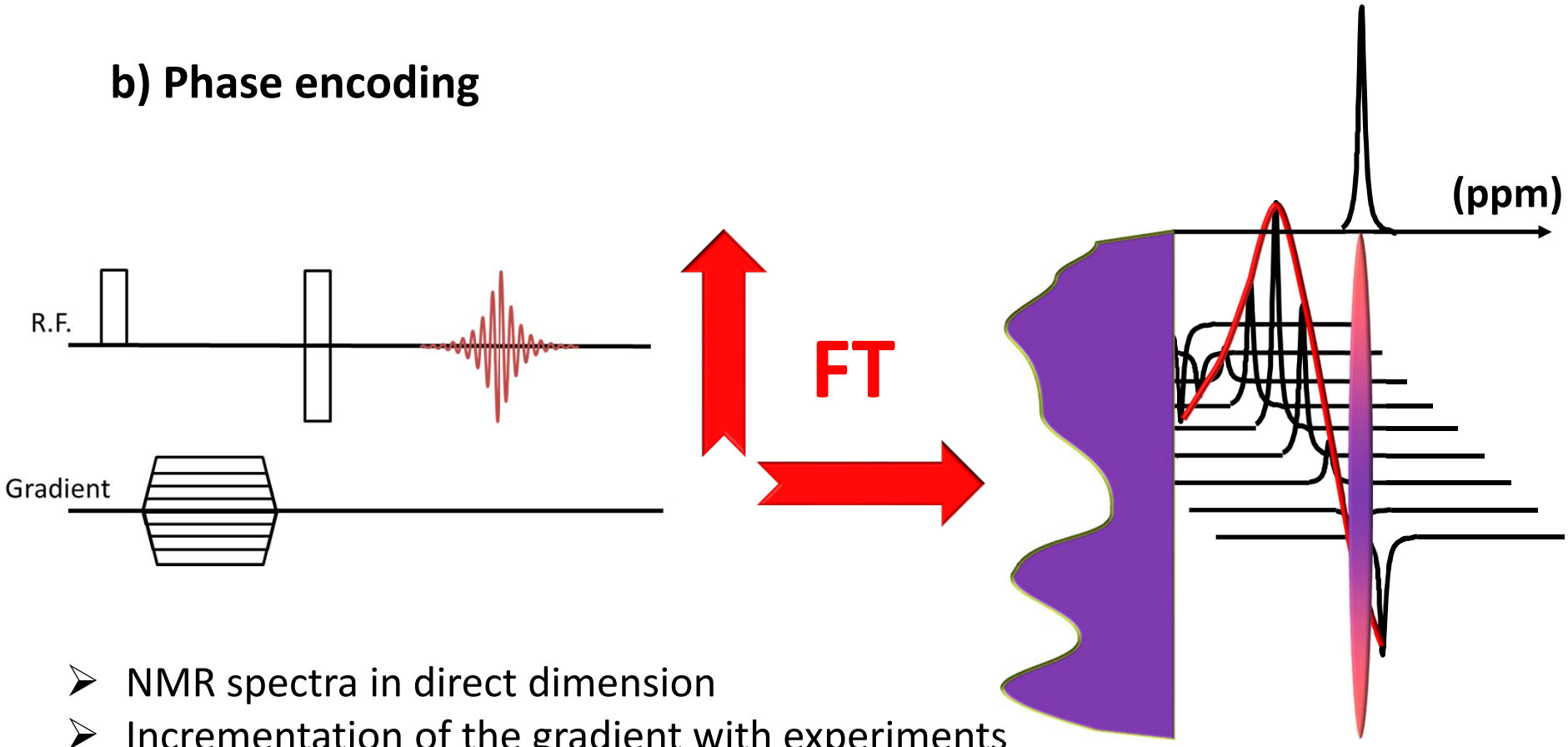
a) Frequency encoding



- Acquisition under gradient
- Frequency dependent of spatial position
- Fourier transform
- Object profile in the gradient direction

II) Spatial encoding

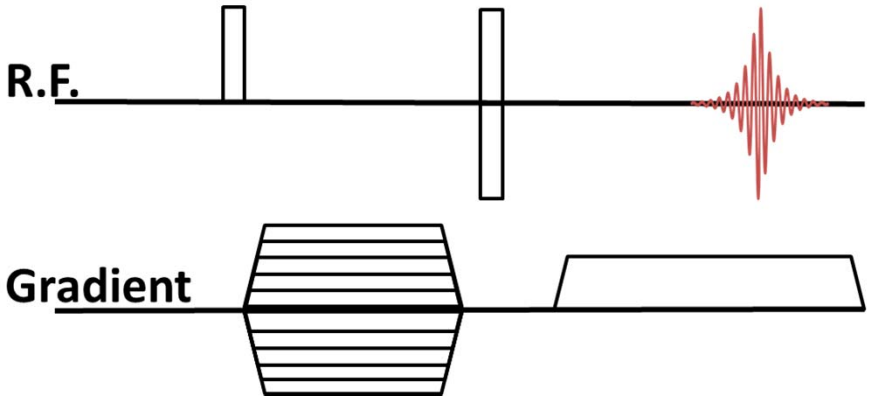
b) Phase encoding

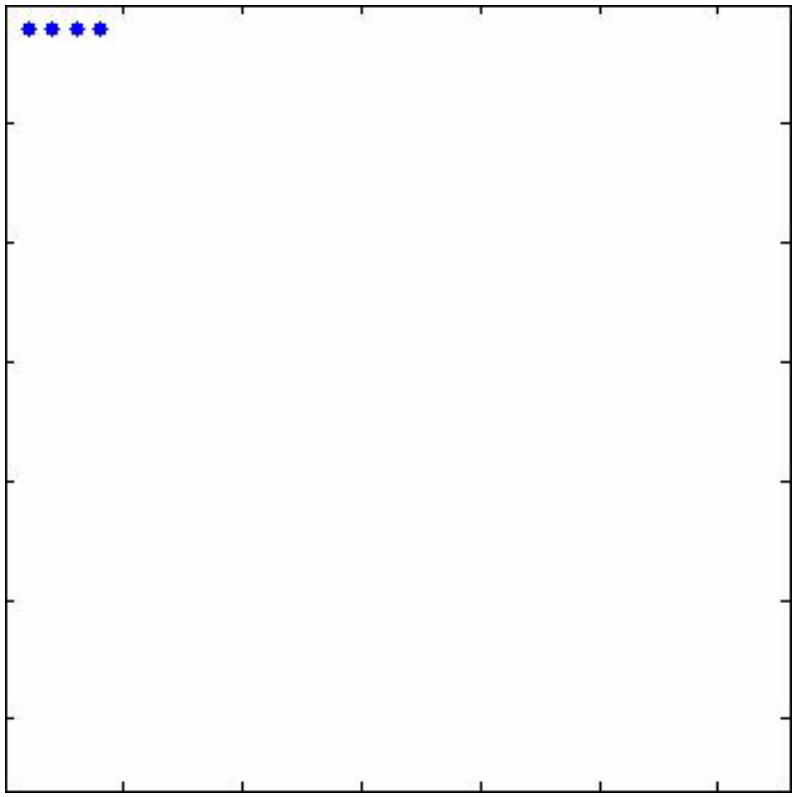


- NMR spectra in direct dimension
- Incrementation of the gradient with experiments
- Incrementation of the phase as function as felt gradient and thus spatial position of each resonance
- Fourier transform in the spatial dimension -> object profile

II) Spatial encoding

c) Reciprocal space: K-space



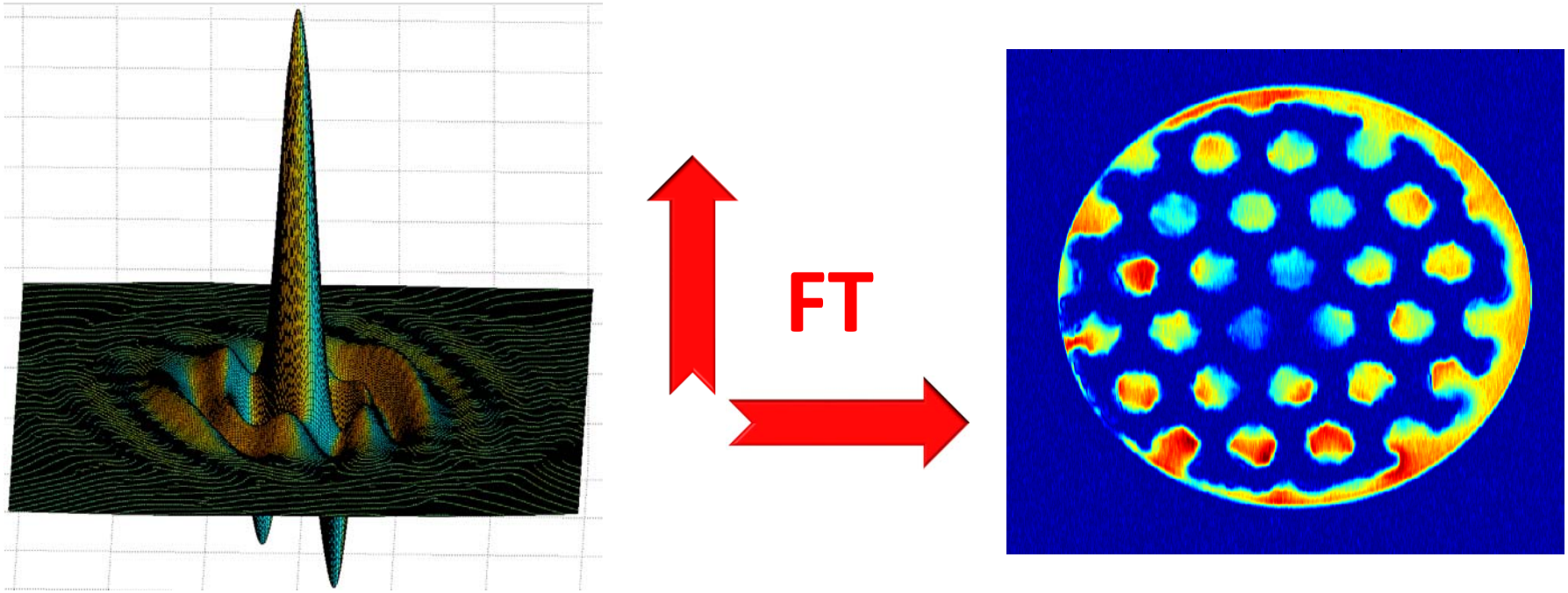


- The combination of these two encoding allow the acquisition of multiple dimension images

- The recorded data is the reciprocal space of an image: the K-space

III) Processing

c) Reciprocal space: K-space



- A Fourier transform in the two direction of this reciprocal space give the image

III) Processing

a) Matlab

- Import the NMR data

```
fid=fopen(/mySERfile,'r','l');
[data,~]=fread(fid,'int32');
```

- Cut them and arrange them to retrieve the reciprocal space

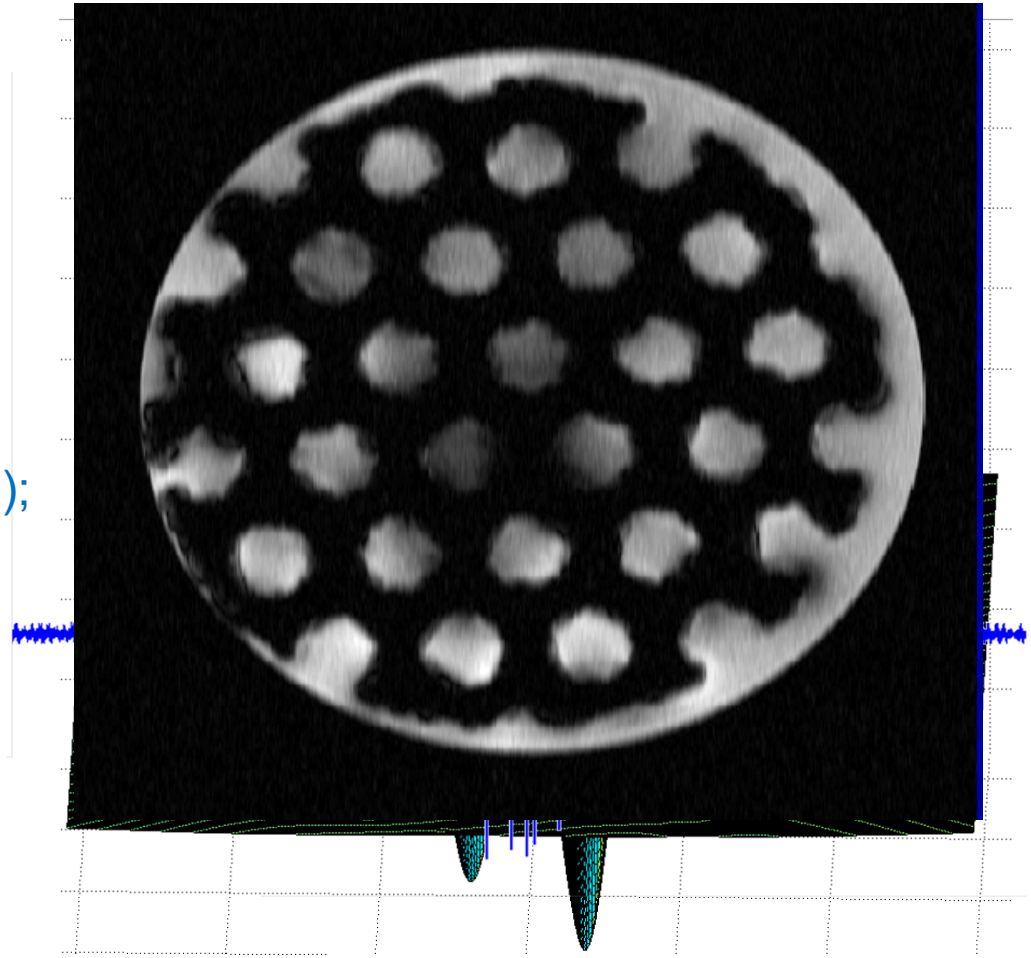
```
data2D = reshape(data,TD2,TD1));
```

- Perform the double Fourier transform to obtain the image

```
image = abs(fftshift(fft2(data2D)));
```

- Display the image

```
imagesc(image)
colormap gray
```

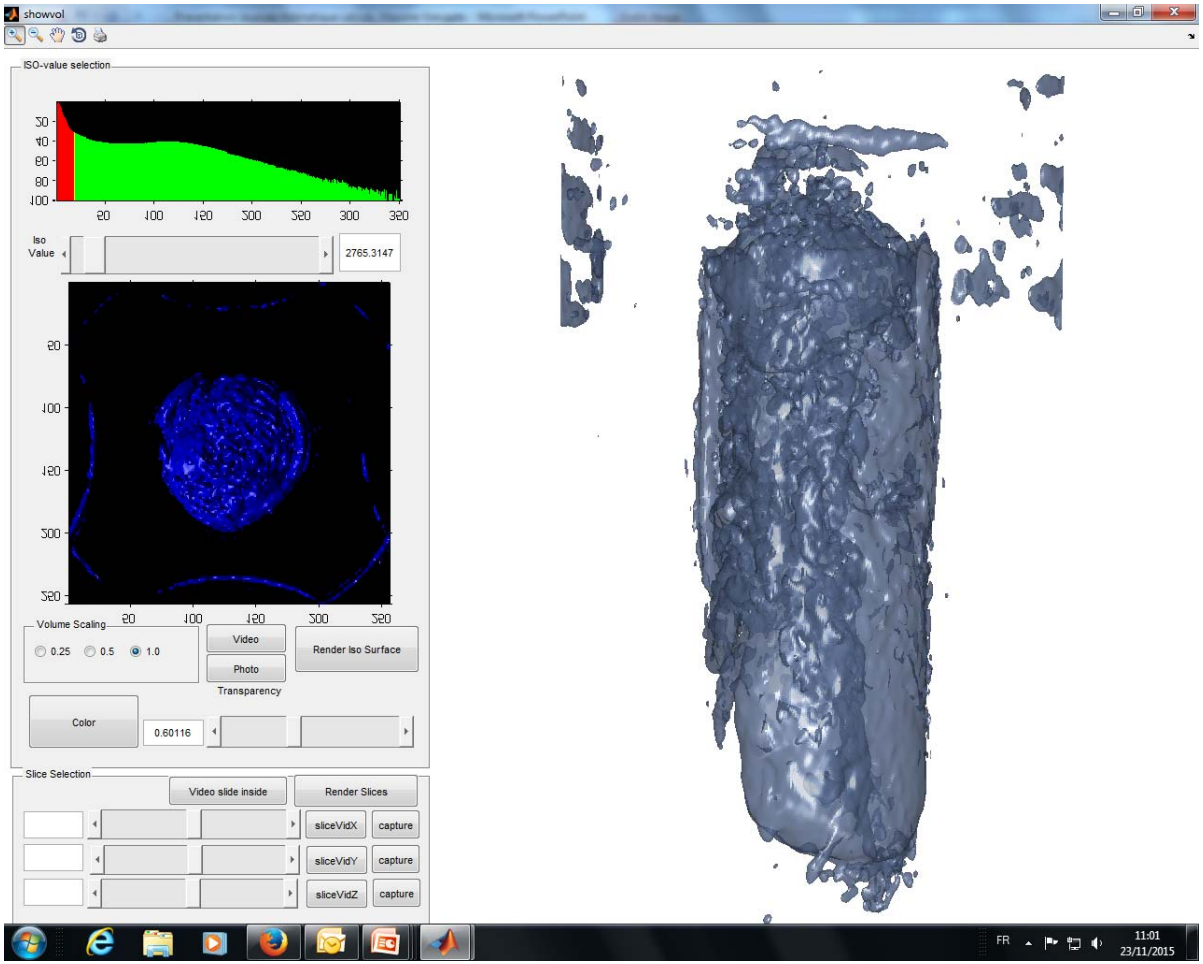


IV) Display

a) 3D display

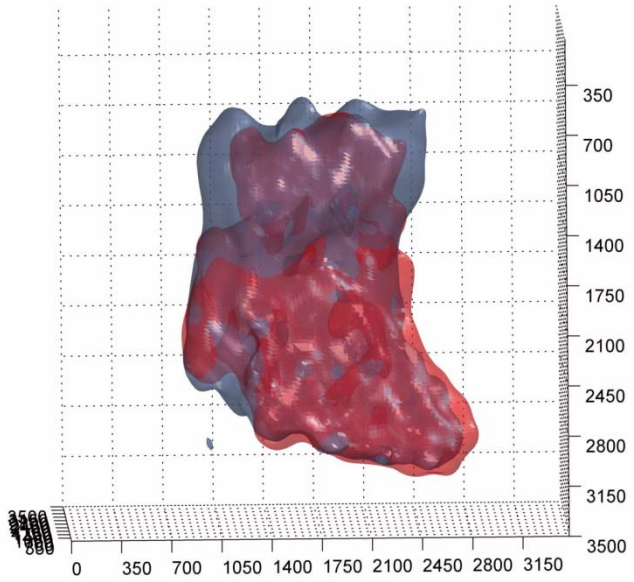
- The result of a 3D acquisition and processing is a square matrix full of intensity point

- In order to display the surface of the 3D image, a cut off value is required



IV) Display

b) 3D display



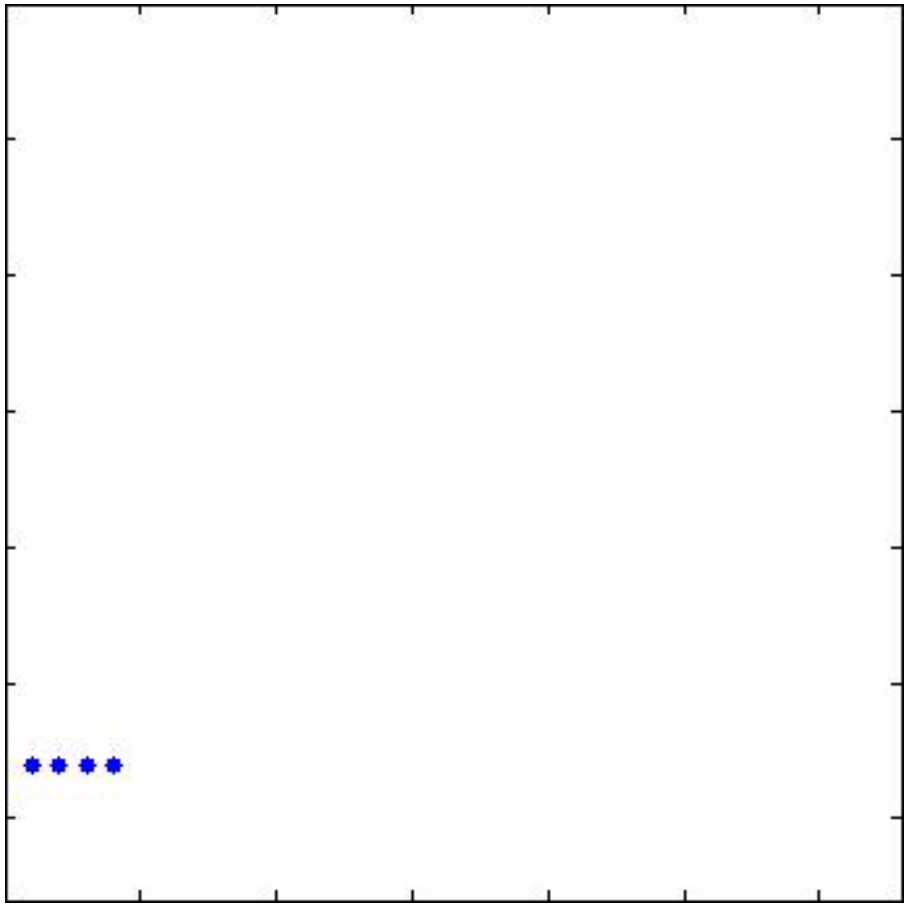
- The Matlab display is also important to allows the user to see all the information in the 3D image

V) Reconstruction

a) Sparse sampling

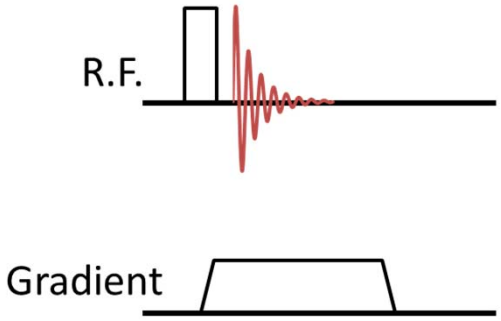
- The reciprocal space of the image contain more signal in the center and redundant information
- It is possible to acquired only a part of it and then reconstruct the full K-space.
- This sampling reduce the experimental time

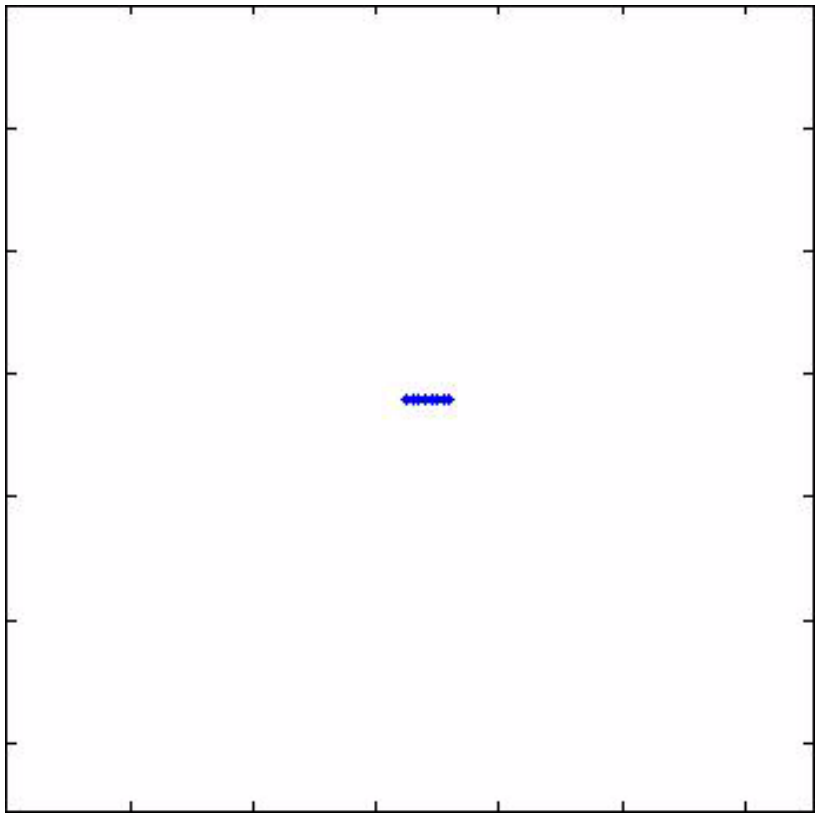
```
recKspace=griddata(Xcoord,Ycoord,
data,Xq,Yq,'cubic');
```



V) Reconstruction

c) Radial sampling





- The acquisition of the reciprocal space of the image can be perform by different trajectories
- The radial sampling allows to image a signal with a short life time

V) Reconstruction

b) Non Cartesian sampling

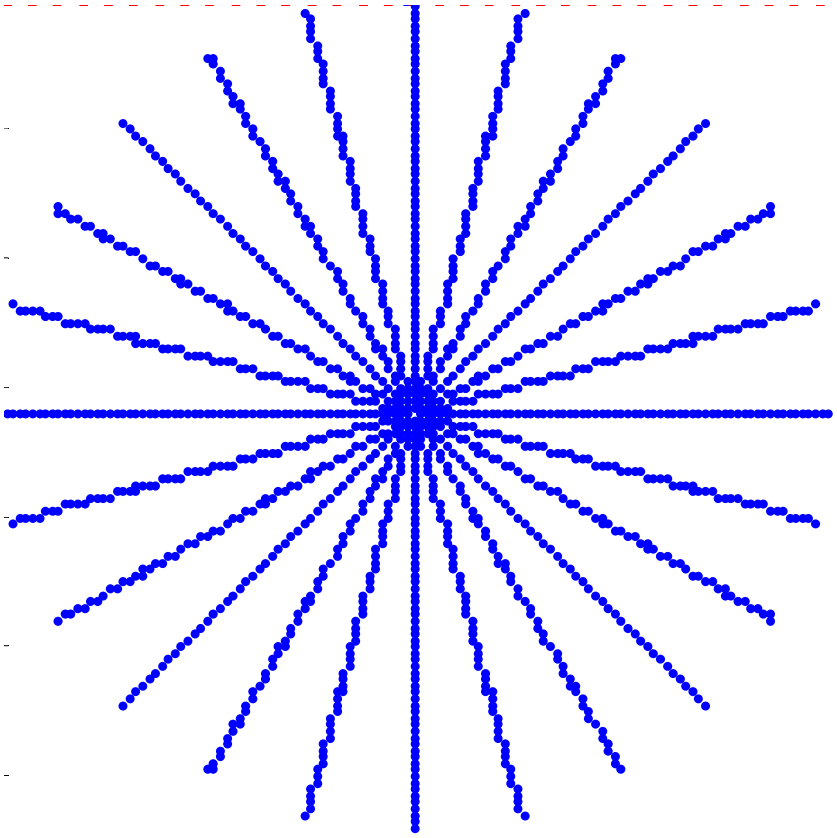
- After the acquisition a Cartesian map off points has to be computed before Fourier transform

- This can be done by interpolation

```
recKspace=griddata(Xcoord,Ycoord,
data,Xq,Yq,'cubic');
```

- Or by Fourier transform of the radius and Radon transform of the projections

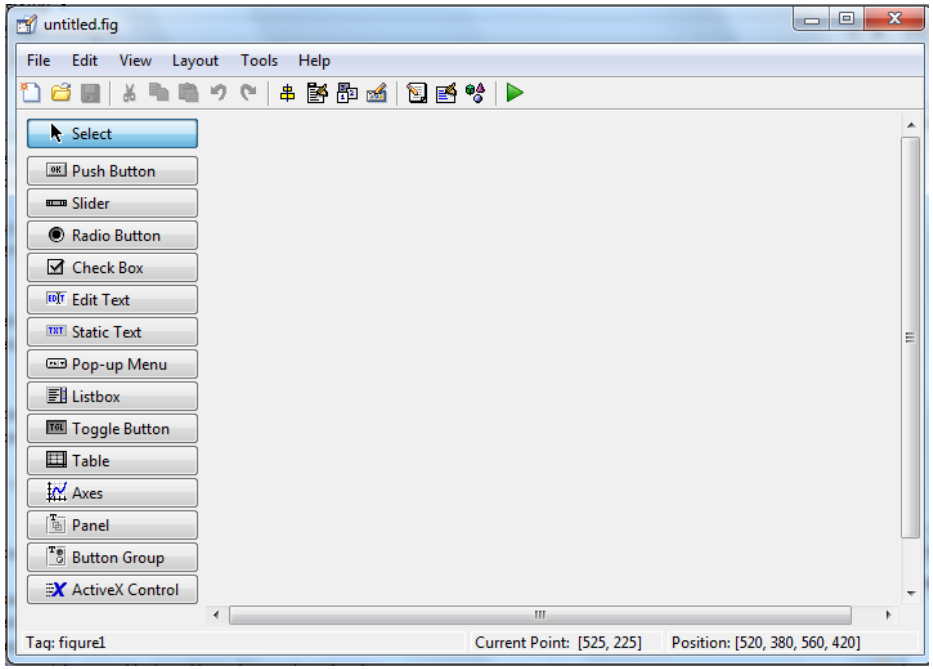
```
imageradon=iradon(projections,angle);
```



VI) Standalone Application

a) Application

- Sometime it is not convenient to open Matlab, just to display your data
- The Matlab compiler allows to execute all the treatments outside Matlab
- Your application will be able to run on any computer and be shared with users which do not possess Matlab
- It is easy to create



Conclusion

a) Magnetic resonance imaging (MRI)

- The Magnetic Resonance Imaging do not give directly images but spatially encoded data

- The image is obtain by Fourier transform of these data

- Matlab can be a valuable tool to :
  - Display the images
  - Create your own processing easily
  - Share this processing with everyone on any computer

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