3D Reconstruction & Fitting

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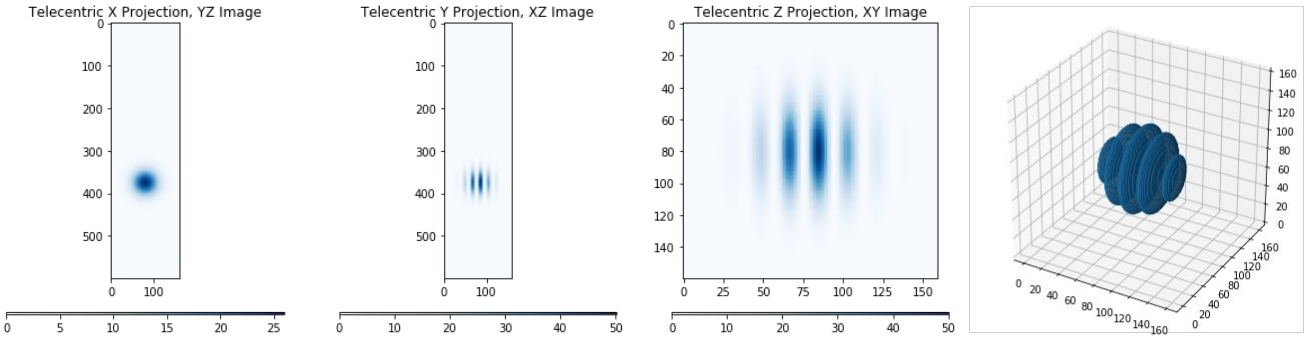
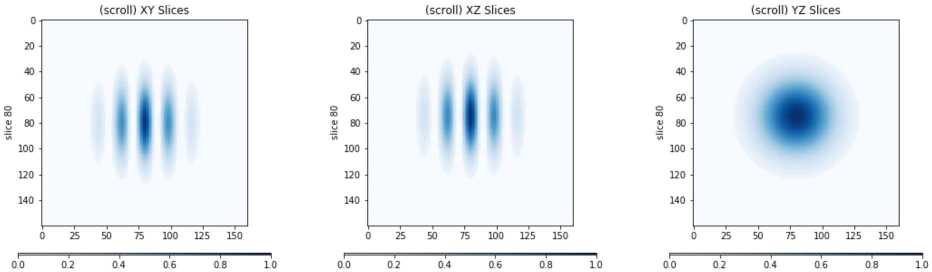
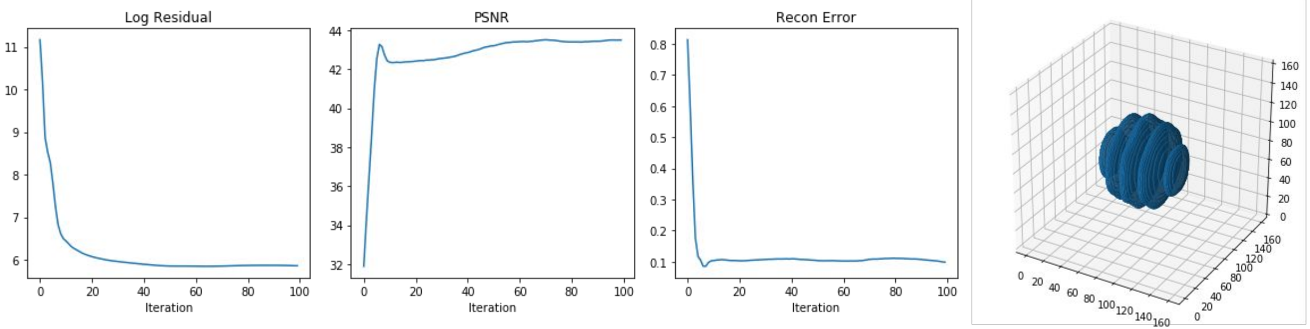
$$\frac{i\left(\frac{2}{\pi}\right)^{3/4}(m w_0)^{3/2}\left(\frac{1}{\sqrt{2}}+\frac{e^{i\left(\text{aQuad kFringe}^{2} x^2+\text{kFringe } x\right)+i\phi}}{\sqrt{2}}\right)e^{-\frac{m\left((x-x_A)^2+(y-y_A)^2+(z-z_A)^2\right)}{4mw_0^2+2i\,\text{tFinalBS}\,\hbar}}}{\sqrt{-\left(2mw_0^2+i\,\text{tFinalBS}\,\hbar\right)^3}}$$

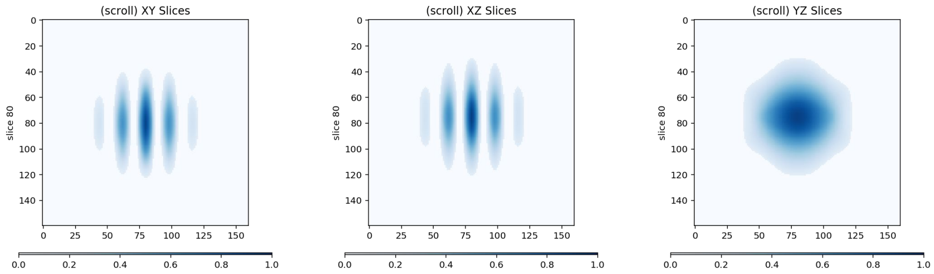
Inputs





Current best 3D reconstruction

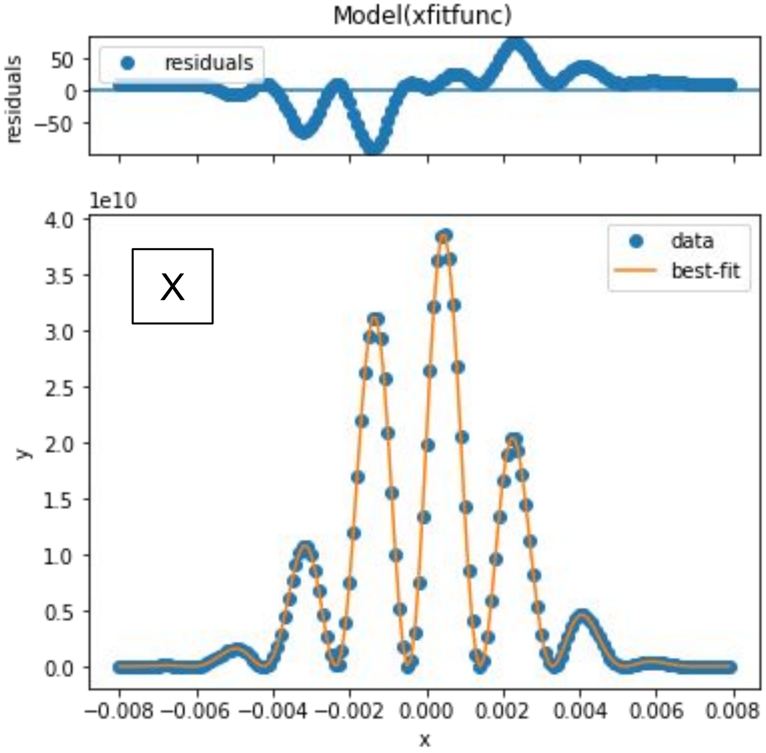




1D Fitting

$$A \cdot N \cdot \left(1+\cos\left(\frac{2\pi x}{\lambda \cdot M}+Q\cdot\left(\frac{2\pi x}{\lambda \cdot M}\right)^2+\phi\right)\right)\cdot\frac{e^{-\frac{(x-\mu\cdot M)^2}{2\sigma\cdot M^2}}}{\sqrt{2\pi}\sigma\cdot M}+pixelnoise$$

Using Truth Data

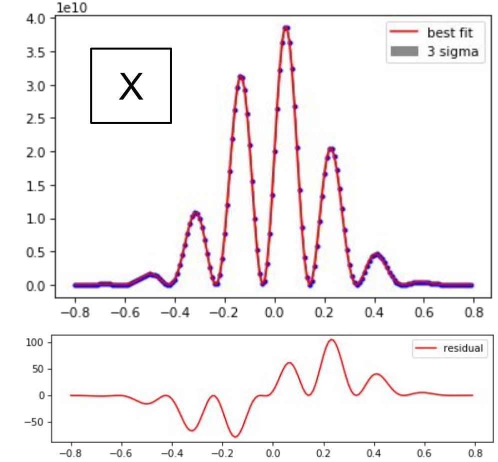


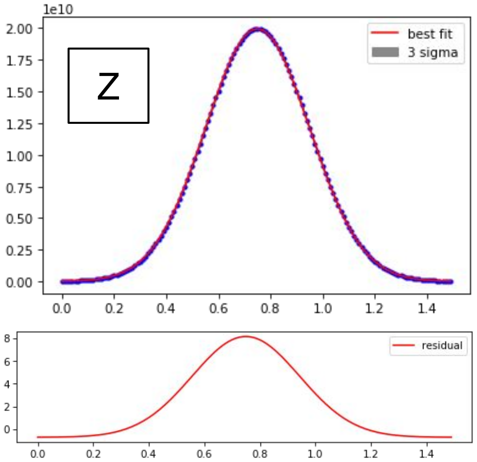
[[Model]]
Model(xfitfunc)
[[Fit Statistics]]
fitting method = leastsq
function evals = 406
data points = 160
variables = 5
chi-square = 151770.399
reduced chi-square = 979.163864
Akaike info crit = 1106.79205
Bayesian info crit = 1122.16792
[[Variables]]
A: 5.6405e+11 +/- 158.660583 (0.00%) (init = 100000)
mu: 7.1959e-12 +/- 3.1796e-13 (4.42%) (init = 0)
sigma: 0.00112838 +/- 3.7419e-13 (0.00%) (init = 0.005)
pixel_noise: 11.6778724 +/- 1.95800145 (16.77%) (init = 0)
phi: -1.57079633 +/- 3.8055e-10 (0.00%) (init = 0)
[[Correlations]] (unreported correlations are < 0.100)
C(A, sigma) = 0.631
C(sigma, pixel_noise) = -0.362
C(A, pixel_noise) = -0.344
C(mu, phi) = -0.201
C(mu, sigma) = -0.126
C(mu, pixel_noise) = -0.103

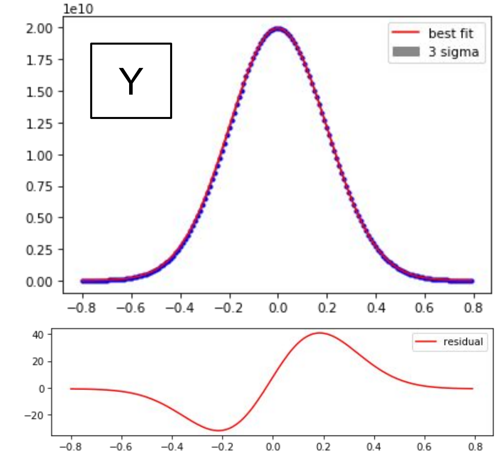
3D Fitting

$$A\cdot N\cdot\left(1+\cos\left(\frac{2\pi x}{\lambda\cdot M}+Q\cdot\left(\frac{2\pi x}{\lambda\cdot M}\right)^2+\phi\right)\right)\cdot\frac{e^{-\frac{(x-\mu\cdot M)^2}{2\sigma\cdot M^2}}}{\sqrt{2\pi}\sigma\cdot M}+pixelnoise$$

Using Truth Data





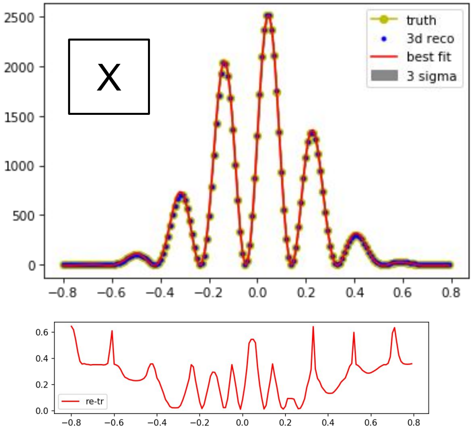


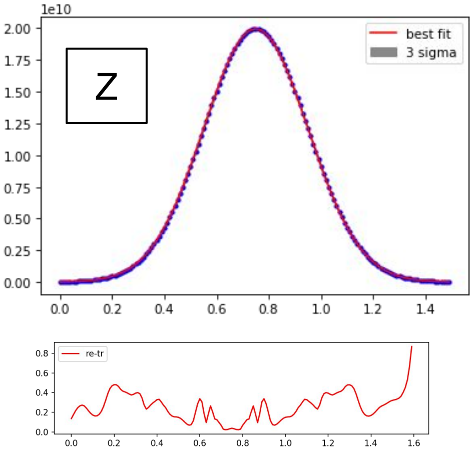
parameter names: ['A', 'mux', 'muy', 'muz', 'sigma', 'pixel_noise', 'phi']
independent variables: ['x', 'y', 'z']
cloud made
(3840000, 1) (3840000, 1) (3840000, 1) (3840000, 1)
[[Model]]
    Model(threedfullfitfunc)
[[Fit Statistics]]
    # fitting method   = leastsq
    # function evals   = 74
    # data points   = 3840000
    # variables   = 7
    chi-square   = 55.3887696
    reduced chi-square = 1.4424e-05
    Akaike info crit   = -42802953.3
    Bayesian info crit = -42802861.2
[[Variables]]
    A: 2.2448e+08 +/- 4.5595e-04 (0.00%) (init = 5.6e+11)
    mux: -8.2500e-12 +/- 1.9840e-15 (0.02%) (init = 0)
    muy: -5.9668e-12 +/- 3.9972e-15 (0.07%) (init = 0)
    muz: 0.00750000 +/- 5.2360e-15 (0.00%) (init = 0)
    sigma: 0.00112838 +/- 1.7071e-15 (0.00%) (init = 0.00112837)
    pixel_noise: 2.8226e-05 +/- 1.5713e-06 (5.57%) (init = 0)
    phi: -1.57079633 +/- 3.2065e-12 (0.00%) (init = -1.570796)
[[Correlations]] (unreported correlations are < 0.100)
    C(A, sigma) = -0.375
    C(A, mux)   = -0.175

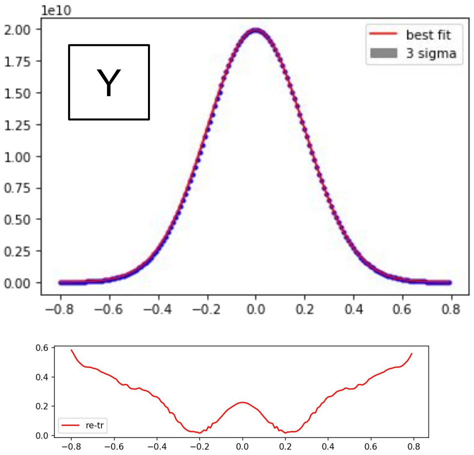
3D Fitting

$$A\cdot N\cdot\left(1+\cos\left(\frac{2\pi x}{\lambda\cdot M}+Q\cdot\left(\frac{2\pi x}{\lambda\cdot M}\right)^2+\phi\right)\right)\cdot\frac{e^{-\frac{(x-\mu\cdot M)^2}{2\sigma\cdot M^2}}}{\sqrt{2\pi}\sigma\cdot M}+pixelnoise$$

Using 3D Recon.








```
parameter names: ['A', 'mux', 'muy', 'muz', 'sigma', 'pixel_noise', 'phi']
independent variables: ['x', 'y', 'z']
cloud made
(3840000, 1) (3840000, 1) (3840000, 1) (3840000, 1)
[[Model]]
    Model(threedfullfitfunc)
[[Fit Statistics]]
    # fitting method   = leastsq
    # function evals   = 82
    # data points      = 4096000
    # variables        = 7
    chi-square         = 58.3112869
    reduced chi-square = 1.4236e-05
    Akaike info crit   = -45710222.8
    Bayesian info crit = -45710130.2
[[Variables]]
    A:            14.3273670 +/- 4.4480e-04 (0.00%) (init = 1)
    mux:         -1.5442e-06 +/- 8.2347e-08 (5.33%) (init = 0)
    muy:         -8.9271e-09 +/- 8.2345e-08 (922.42%) (init = 0)
    muz:          0.00750000 +/- 8.2347e-08 (0.00%) (init = 0)
    sigma:        0.00115191 +/- 2.8242e-08 (0.00%) (init = 0.00112837)
    pixel_noise: -3.2180e-04 +/- 2.0264e-06 (0.63%) (init = 0)
    phi:         -1.57097929 +/- 4.9397e-05 (0.00%) (init = -1.570796)
[[Correlations]] (unreported correlations are < 0.100)
    C(A, sigma)           = -0.317
    C(sigma, pixel_noise) = -0.313
    C(A, pixel_noise)     = -0.124
```

Summary & Next Steps

- Analogue 3D reconstruction looks good
- Results from fitting to 3D geometries with M=1 looks better than 1D fit on truth data
- Fitting on 3D reconstructed data gives lower performance
    - Effect of inadequate modelling function

- Find data-driven way to learn modeling function from 3D recon clouds
- Add in effects of magnification and entocentricity to gauge degradation in performance
- Add effects of sensor imperfections

ML approach

- Many ML approaches to 3D reconstruction in literature
    - DOI: 10.1109/ISBI.2018.8363663
    - DOI: 10.1117/12.2293766
    - arXiv:1709.01841
    - DOI: 10.1088/1361-6420/ab6d57
    - https://openreview.net/forum?id=rJed6j0cKX
- Methods rely on the ability of networks to learn the prior from training data
- Can we generate O(e4-e6) clouds that suitably fill up the physical phase space of clouds we will encounter in MAGIS?
    - Can start at the truth level before adding in detector effects