Lab Notebook

Pupil Reconstruction

Daniel Carmona

Contents

1 Amplitude and Phase Reconstruction

16 February 2024

- Create new github branch: `AmpPhaseReconstructionRetraining`
- Download the following the files from Morgana:
  - `superK_slmcube_20230625_complsines-01sp_07`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file00`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file01`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file02`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file03`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file04`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file05`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file06`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file07`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file08`
  - `slmcube_20230625_complsines-01sp_07_PSFWFs_file09`
- Data processing for Fully Convolutional NN training
- One fast experiment for each file: very good results, around 0.05 validation mse

19 February 2024

- Remove normalization from amplitude and phase for the fully connected experiments

---

EXPERIMENT NewFC10000-Processed 2

HYPERPARAMETERS:

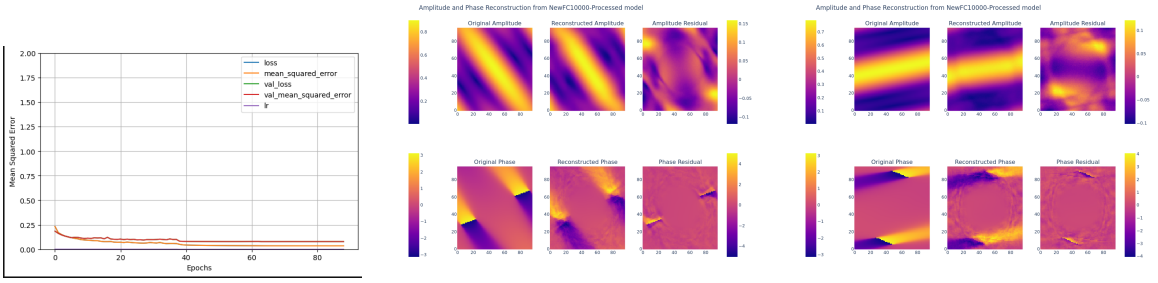
```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 1320
  -Output shape: (2, 96, 96)
  -Hidden layers: [2000, 2000, 2000, 2000]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE
```

```
*TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.035130929201841354
      -Validation MSE: 0.0786573588848114
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 1: Results of training the model NewFC10000-Processed 2

EXPERIMENT NewFC30000-Processed-1

HYPERPARAMETERS:

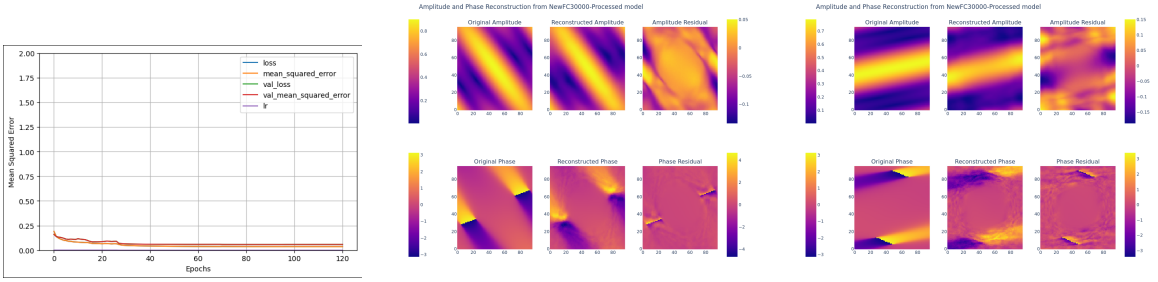
```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 1320
  -Output shape: (2, 96, 96)
  -Hidden layers: [2000, 2000, 2000, 2000]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.0357743538916111
      -Validation MSE: 0.057852283120155334
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 2: Results of training the model NewFC30000-Processed-1

EXPERIMENT NewFC80000-Processed-1

HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 1320
  -Output shape: (2, 96, 96)
  -Hidden layers: [2000, 2000, 2000, 2000]
  -Regularizer: None
  -Hidden Layers Activation: relu
```

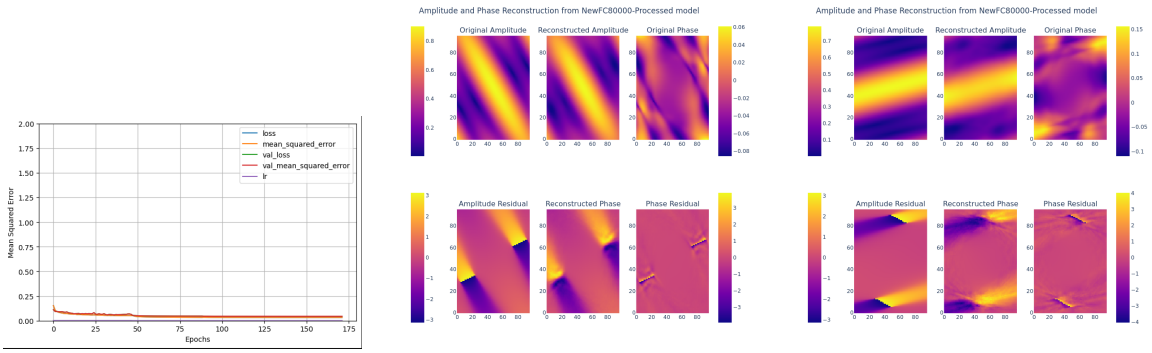
```
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.03301804140210152
      -Validation MSE: 0.04487497732043266
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 3: Results of training the model NewFC80000-Processed-1

- Normalize and split fluxes in train, validation and test files
- Stack amplitude and phase arrays and save in train, validation and test files

---

EXPERIMENT NewConv10000-1

HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Convolutional
  -Input shape: (55, 24, 1)
  -Output shape: (96, 96, 2)
  -Convolutional Layers: [128, 256, 512]
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3)]
```

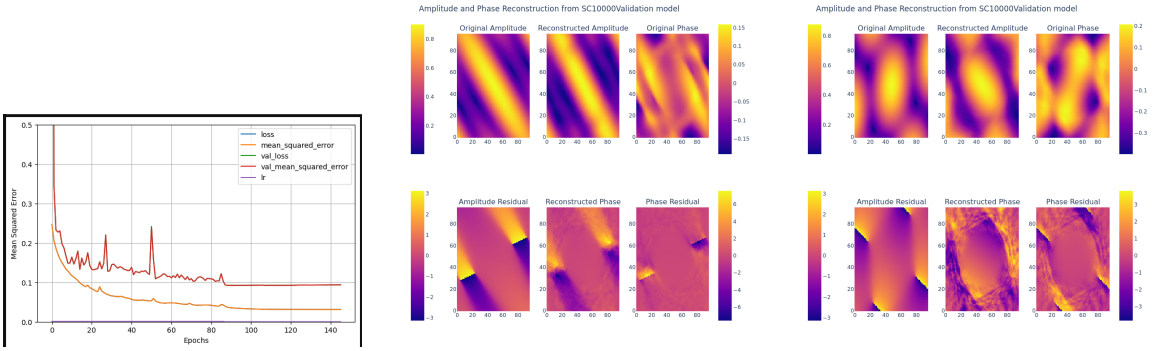
```
  -Fully Connected Hidden layers: [4096, 2048, 2048, 1024, 1024, 102
  -Regularizer: None
  -Convolutional Activation: relu
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: True

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

* TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 15 x0.1
    -Early Stop: MSE 50
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.031087761744856834
      -Validation MSE: 0.09376049041748047
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 4: Results of training the model NewConv10000-1

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EXPERIMENT NewConv30000-1

HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Convolutional
  -Input shape: (55, 24, 1)
  -Output shape: (96, 96, 2)
  -Convolutional Layers: [128, 256, 512]
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3)]
```

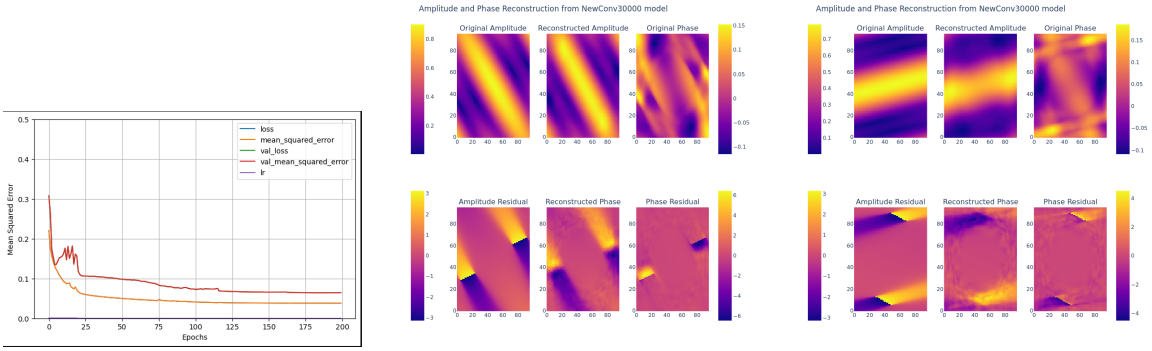
```
  -Fully Connected Hidden layers: [4096, 2048, 2048, 1024, 1024, 102
  -Regularizer: None
  -Convolutional Activation: relu
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: True

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

* TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 15 x0.1
    -Early Stop: MSE 50
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.03819489851593971
      -Validation MSE: 0.06443119794130325
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 5: Results of training the model NewConv30000-1

EXPERIMENT NewConv30000-1

HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Convolutional
  -Input shape: (55, 24, 1)
  -Output shape: (96, 96, 2)
  -Convolutional Layers: [128, 256, 512]
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3)]
  -Fully Connected Hidden layers: [4096, 2048, 2048, 1024, 1024, 102
  -Regularizer: None
  -Convolutional Activation: relu
  -Hidden Layers Activation: relu
```

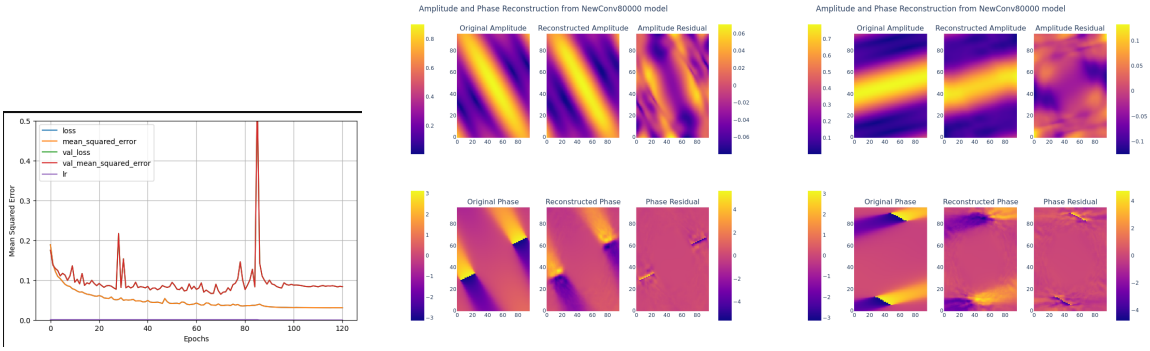
```
  -Output Layer Activation: linear
  -Batch Normalization: True

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

* TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 15 x0.1
    -Early Stop: MSE 50
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.030630357563495636
      -Validation MSE: 0.08355200290679932
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 6: Results of training the model NewConv80000-1

- Normalize flux data and add padding for flux autoencoder
- Stack amplitude and phase and add padding for encoder+convolutional model

---

EXPERIMENT NewFluxAutoencoder10000-1

HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Autoencoder
  -Input shape: (56, 24, 1)
  -Convolutional Layers: [512, 128, 64, 8]
    (Inverse in the decoder)
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3), (3, 3)]
```

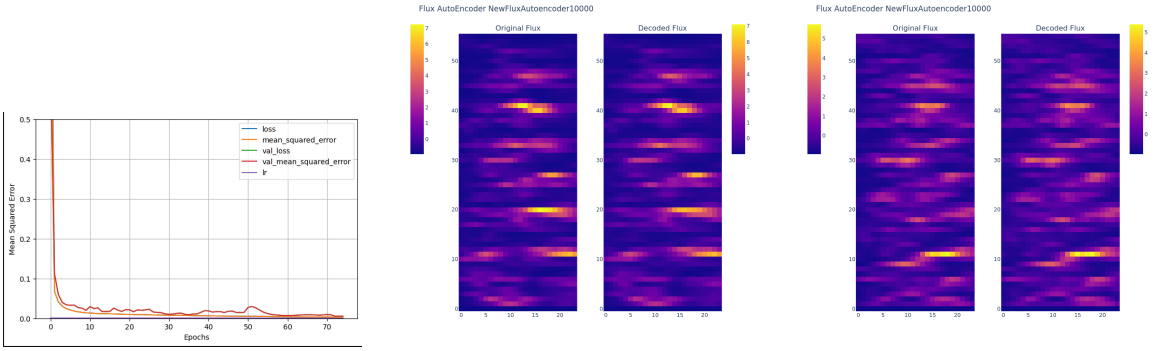
```
    (Inverse in the decoder)
  -Convolutional Activation: relu
  -Output Layer Activation: linear
  -Padding: same
  -Use Batch Normalization: True

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 75
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 8 x0.1
    -Early Stop: MSE 15
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.0018673702143132687
      -Validation MSE: 0.005482238717377186
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 7: Results of training the model NewFluxAutoencoder10000-1

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EXPERIMENT NewFluxAutoencoder80000-1

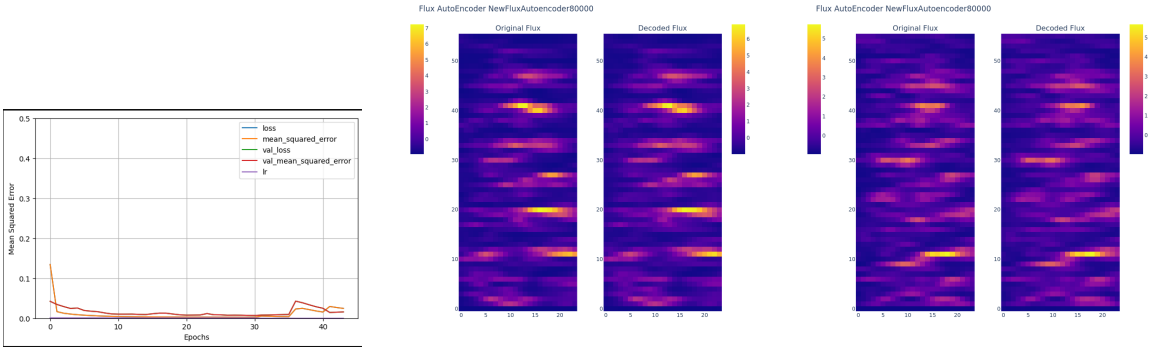
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Autoencoder
  -Input shape: (56, 24, 1)
  -Convolutional Layers: [512, 128, 64, 8]
    (Inverse in the decoder)
```

```
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3), (3, 3)]
    (Inverse in the decoder)
  -Convolutional Activation: relu
  -Output Layer Activation: linear
  -Padding: same
  -Use Batch Normalization: True

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 75
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 8 x0.1
    -Early Stop: MSE 15
```

VISUALIZATION:

```
      -Train MSE: 0.024667566642165184
      -Validation MSE: 0.0158506091684103
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 8: Results of training the model NewFluxAutoencoder10000-1

EXPERIMENT NewEncConv10000-1

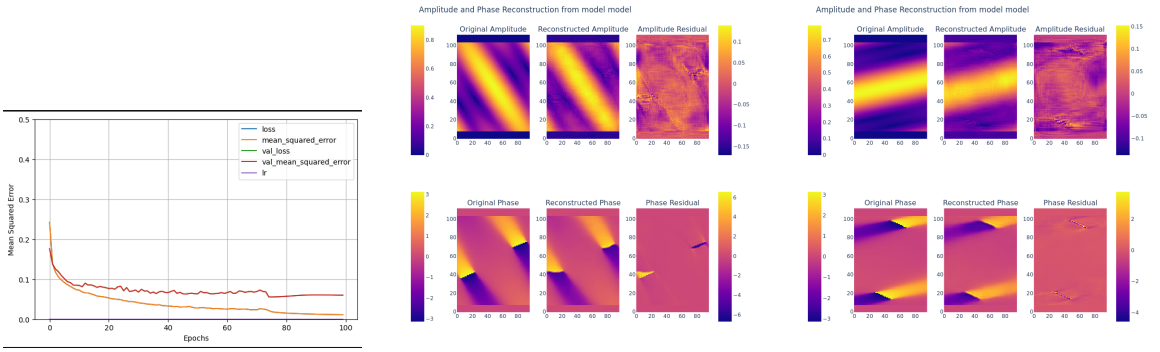
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Encoder + Convolutional
  -Convolutional Layers: [1024, 512, 256, 256]
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3), (3, 3)]
  -Convolutional Activation: relu
  -Output Layer Activation: linear

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.0001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
```

```
   -Metric: MSE


* TRAINING HYPERPARAMETERS:
   -Epochs: 100
   -Batch size: 32
   -Callbacks:
      -ReduceLROnPlateau: MSE 8 x0.1
      -Early Stop: MSE 15
```

VISUALIZATION:

```
*RESULTS:
       -Train MSE: 0.011328332126140594
       -Validation MSE: 0.06024651601910591
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 9: Results of training the model NewEncConv10000-1

EXPERIMENT NewEncConv30000-1

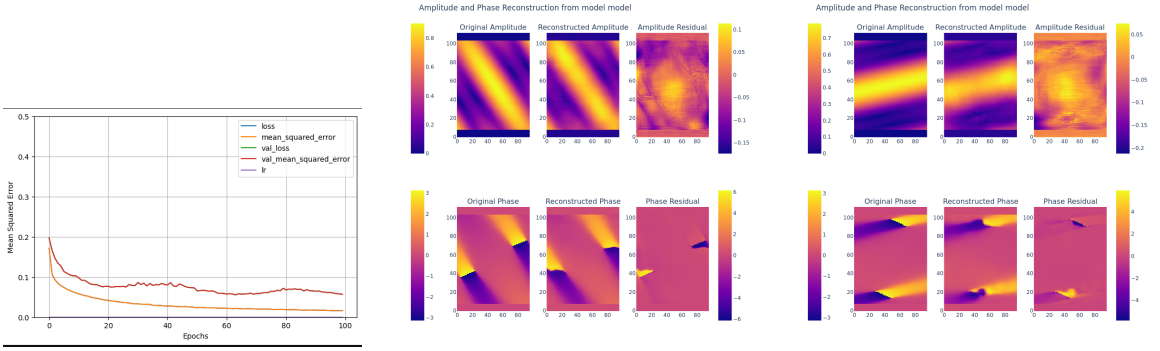
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Encoder + Convolutional
  -Convolutional Layers: [1024, 512, 256, 256]
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3), (3, 3)]
  -Convolutional Activation: relu
  -Output Layer Activation: linear

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.0001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

* TRAINING HYPERPARAMETERS:
  -Epochs: 100
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 8 x0.1
    -Early Stop: MSE 15
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.016221819445490837
```

```
-Validation MSE: 0.05662507936358452
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 10: Results of training the model NewEncConv30000-1

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EXPERIMENT NewEncConv80000-1

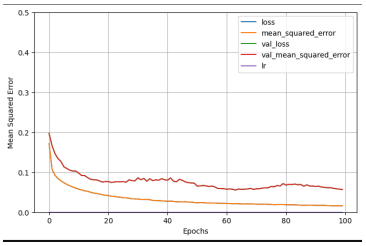
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Encoder + Convolutional
  -Convolutional Layers: [1024, 512, 256, 256]
```

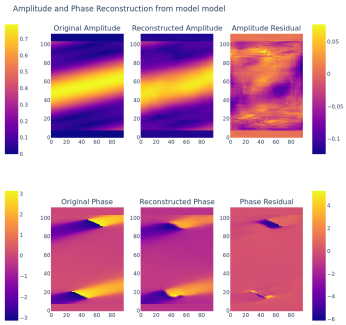
```
  -Convolutonal Kernels: [(3, 3), (3, 3), (3, 3), (3, 3)]
  -Convolutional Activation: relu
  -Output Layer Activation: linear

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.0001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

* TRAINING HYPERPARAMETERS:
  -Epochs: 100
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 8 x0.1
    -Early Stop: MSE 15
```

VISUALIZATION:

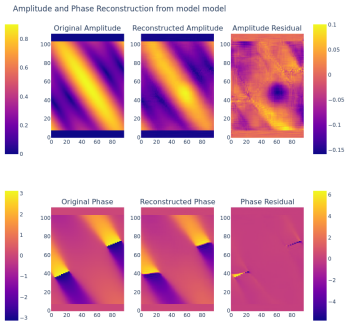
```
*RESULTS:
      -Train MSE: 0.0163
      -Validation MSE: 0.0369
```



(a) IGNORE THIS EVOLUTION FIGURE, TRAINING FINISHED BEFORE STORING THE HISTORY, THIS IS FROM THE PREVIOUS EXPERIMENT



(b) Validation example



(c) Train example

Figure 11: Results of training the model NewEncConv80000-1

2 PSF Reconstruction

20 February 2024

- Create custom dynamic dataloader for PL output flux and PSF complex field for PSF reconstruction

26 February 2024

- Create a dataloader to dynamically load flux and psf
- Normalize electric fields, real and imaginary parts independently
- Normalize PL output fluxes
- Train a fully connected nn with horrible results, train mse keeps stable at 1, will have to look at the data

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27 February 2024

- Create plotting functions to show amplitude, phase and intensity from an electric field
- Normalize electric field, this time dividing the complex number matrix by a constant (50.000 in this case)
- Redo output flux calculation with the normalized electric fields through the transfer matrix of the 19 fibre PL

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28 February 2024

EXPERIMENT PSF-FC-Reconstructor-1

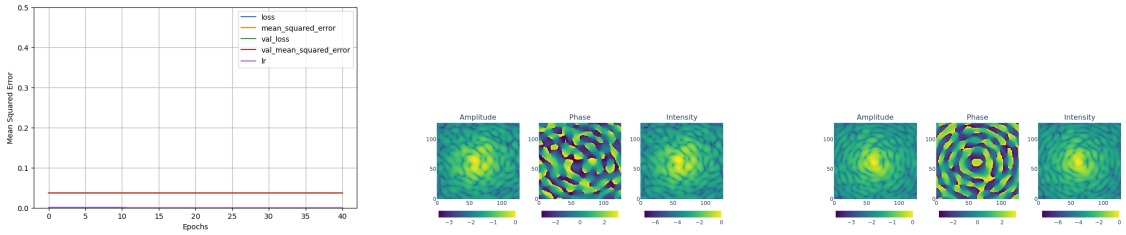
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [2000, 2000, 2000, 2000]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 200
```

```
-Batch size: 64
-Callbacks:
  -ReduceLROnPlateau: MSE 10 x0.1
  -Early Stop: MSE 25
```

VISUALIZATION:

```
    -Train MSE: 0.03701553866267204
    -Validation MSE: 0.03701810911297798
```



(a) Training Evolution (b) Validation prediction (c) Validation original

Figure 12: Results of training the model PSF-FC-Reconstructor-1

29 February 2024

- Create a function to plot amplitude and phase predictions and residuals from a complex field
- Create evaluation notebook
- Since in yesterdays experiment the model does not learn at all, I design two different experiments, to check if there is a problem with the network:

1. A model that sums the output flux of the PL
2. A model that sums the scalars of the complex numbers array containing the electric fields at the pupil.

EXPERIMENT Flux-Sum-1

This model performs a sum of all the output fluxes from the PL

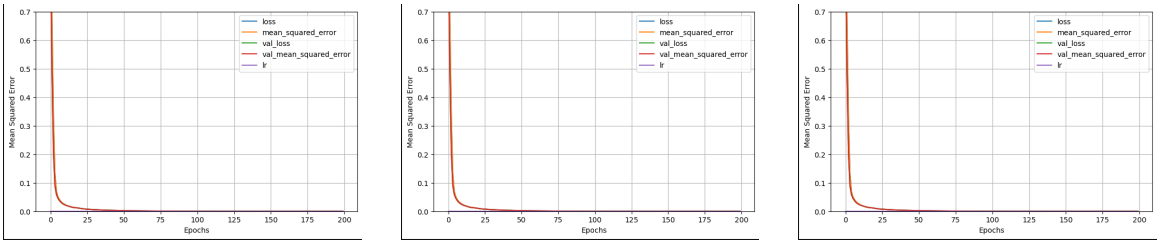
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 1
  -Hidden layers: [100, 100]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.0001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE
```

```
*TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
  *RESULTS:
      -Train MSE: 0.00018273142632097006
      -Validation MSE: 0.00018727070710156113
```



(a) Training Evolution (b) Training Evolution (c) Training Evolution

Figure 13: Results of training the model Flux-Sum-1

EXPERIMENT ElectricField-Sum-1

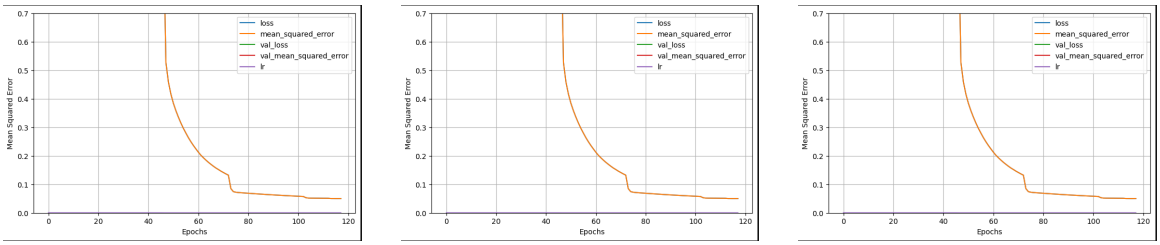
This model performs a sum of all the output fluxes from the PL

HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 32768
  -Output shape: 1
  -Hidden layers: [100, 100, 100]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.0001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
    -Train MSE: 0.050156451761722565
    -Validation MSE: 0.8189939856529236
```



(a) Training Evolution (b) Training Evolution (c) Training Evolution

Figure 14: Results of training the model ElectricField-Sum-1

---

01 March 2024

- Today I decide to train a model with just one datapoint and see if is able to learn the PSF from one flux and one electric field

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EXPERIMENT TestWith1DataPoint-1

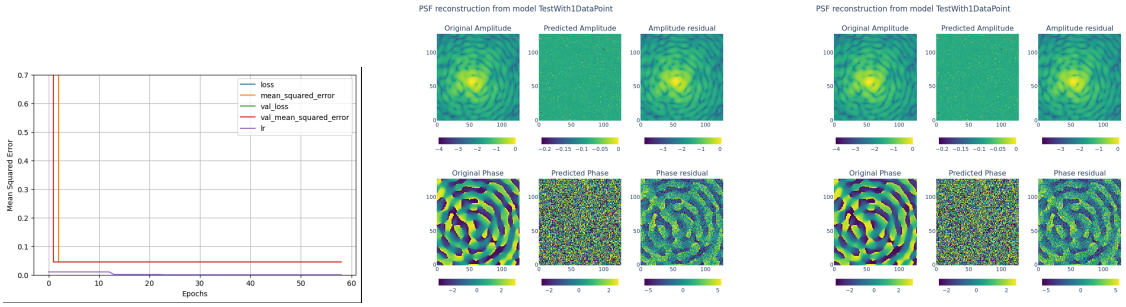
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
```

```
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [1000, 1000, 1000, 1000]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.01, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 1000
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
      -Train MSE: 0.03701553866267204
      -Validation MSE: 0.03701810911297798
```



(a) Training Evolution (b) Train datapoint (c) Train datapoint

Figure 15: Results of training the model TestWith1DataPoint-1

- Something is wrong, going try with a bigger NN, don't think this will change anything but I have to try just in case.

EXPERIMENT TestWith1DataPoint-2

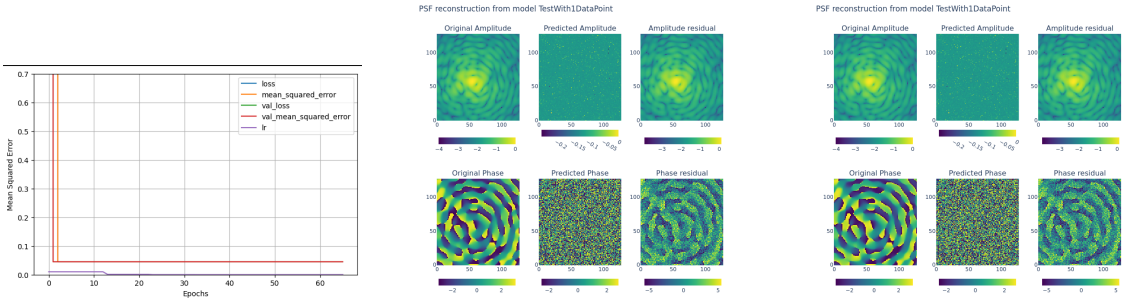
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [128, 128, 128, 128, 256,
          256, 512, 2000, 4000]
  -Regularizer: None
```

```
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.01, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 1000
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.04261719062924385
      -Validation MSE: 0.04261719062924385
```



(a) Training Evolution (b) Train datapoint (c) Train datapoint

Figure 16: Results of training the model TestWith1DataPoint-2

---

04 March 2024

- After seeing that with 1 datapoint the model does not learn I decide to make some simpler tests, I will train a model that from a 19 element array predicts images with 2 channels and see if the input is too small for the model to predict anything. Three experiments will be performed:
  - From a 19 elements array to a 2x128x128 image
  - From a 19 elements array to a 2x64x64 image
  - From a 19 elements array to a 2x32x32 image

EXPERIMENT FromArrayToImage128-1

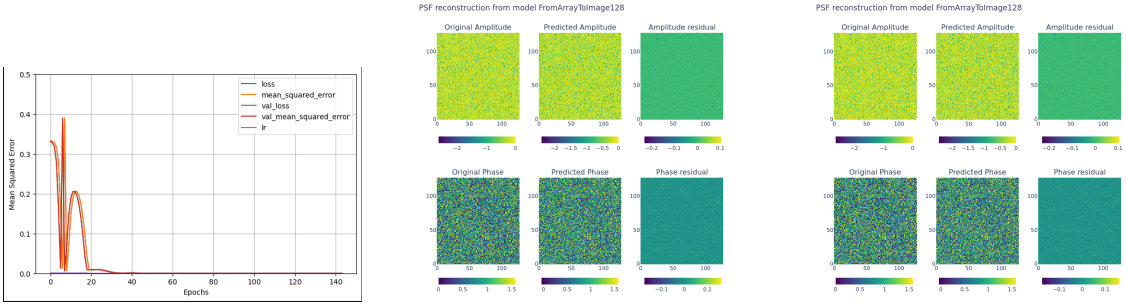
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [128, 128, 128, 128, 256, 256, 512, 2000, 4000]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 10000
  -Batch size: 1
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
```

```
-Train MSE: 0.00010900569031946361
```



(a) Training Evolution (b) Train example (c) Train example

Figure 17: Results of training the model FromArrayToImage128-1

- From the previous experiment it is clear that a 19 element array as input is enough to reconstruct a random image of 2x128x128 resolution, what is happening for the psf reconstruction?.

  I will perform the other 2 stated experiments because it is quite fast.

EXPERIMENT FromArrayToImage64-1

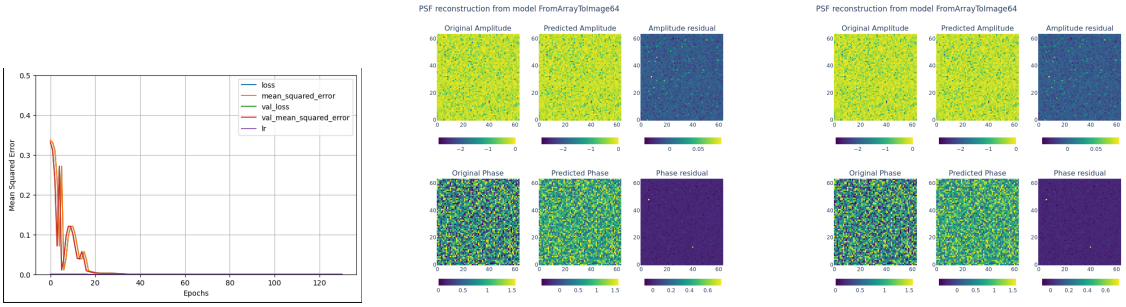
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
```

```
  -Input shape: 19
  -Output shape: 8192
  -Hidden layers: [128, 128, 128, 128, 256, 256, 512, 2000, 4000]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 10000
  -Batch size: 1
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.00012627203250303864
```



(a) Training Evolution (b) Train example (c) Train example

Figure 18: Results of training the model FromArrayToImage64-1

EXPERIMENT FromArrayToImage32-1

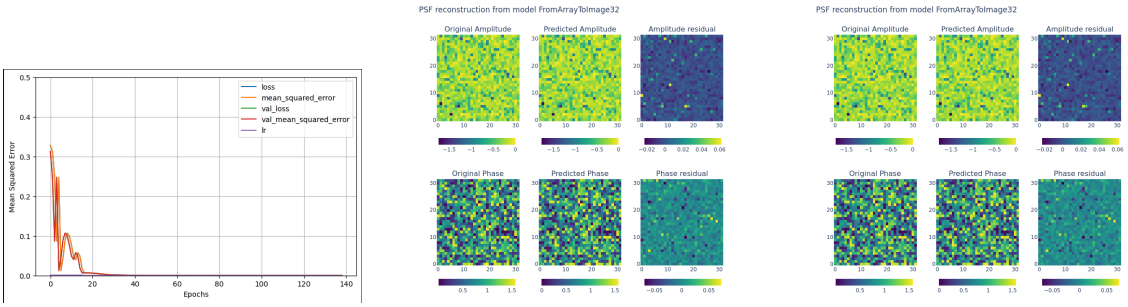
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 2048
  -Hidden layers: [128, 128, 128, 128, 256, 256, 512, 2000, 4000]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2
```

```
*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 10000
  -Batch size: 1
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 5.556200267164968e-05
```



(a) Training Evolution (b) Train example (c) Train example

Figure 19: Results of training the model FromArrayToImage32-1

- The results are satisfactory, I am going to try the exact same configuration for one data point of the PSF dataset and see what happens

---

EXPERIMENT TestWith1DataPoint-3

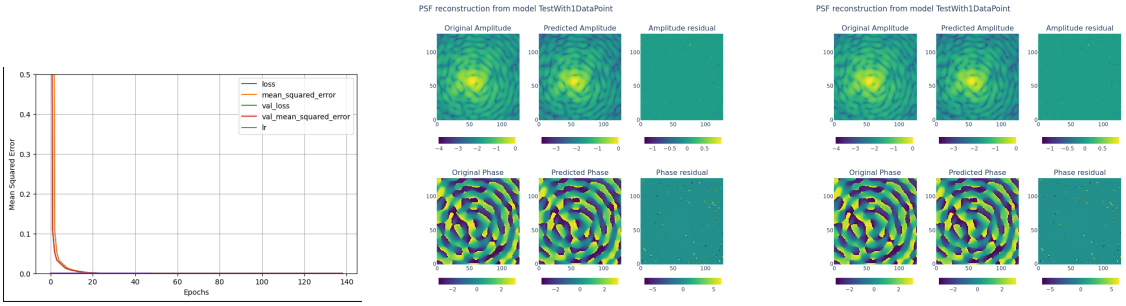
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [128, 128, 128, 128, 256, 256, 512, 2000, 4000]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE
```

```
*TRAINING HYPERPARAMETERS:
  -Epochs: 10000
  -Batch size: 1
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 1.2409615010255948e-05
```



(a) Training Evolution (b) Train datapoint (c) Train datapoint

Figure 20: Results of training the model TestWith1DataPoint-3

- The result has improved incredibly compared to the TestWith1DataPoint-1 and TestWith1DataPoint-2. The only difference I can see are the learning rates and the batch size. I will perform a series of experiments varying batch size: 100 datapoints with 64, 32 and 16 batch size

EXPERIMENT PSFReconstructor-100-64-1

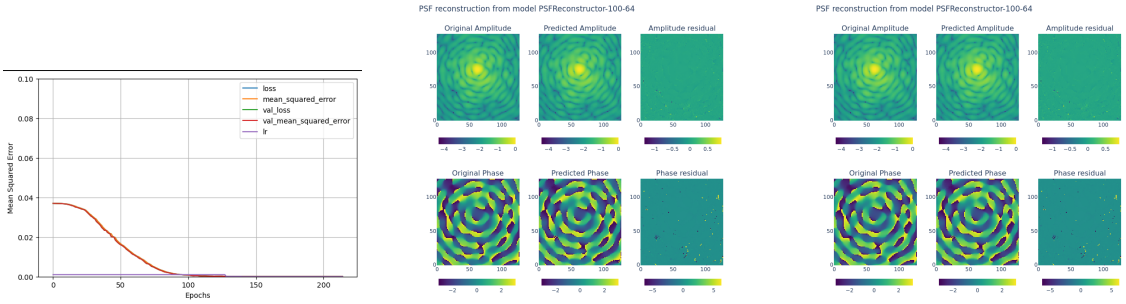
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [128, 128, 128, 128, 256,
          256, 512, 2000, 4000]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 10000
  -Batch size: 64
```

```
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 1.7399888747604564e-05
```



(a) Training Evolution (b) Train datapoint (c) Train datapoint

Figure 21: Results of training the model PSFReconstructor-100-64-1

---

05 March 2024

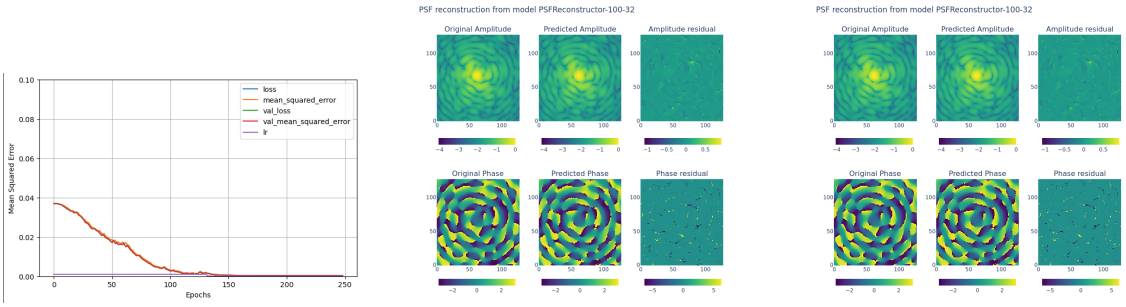
EXPERIMENT PSFReconstructor-100-32-1

HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [128, 128, 128, 128, 256,
          256, 512, 2000, 4000]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 10000
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.00033666446688584983
```



(a) Training Evolution (b) Train datapoint (c) Train datapoint

Figure 22: Results of training the model PSFReconstructor-100-32-1

EXPERIMENT PSFReconstructor-100-16-1

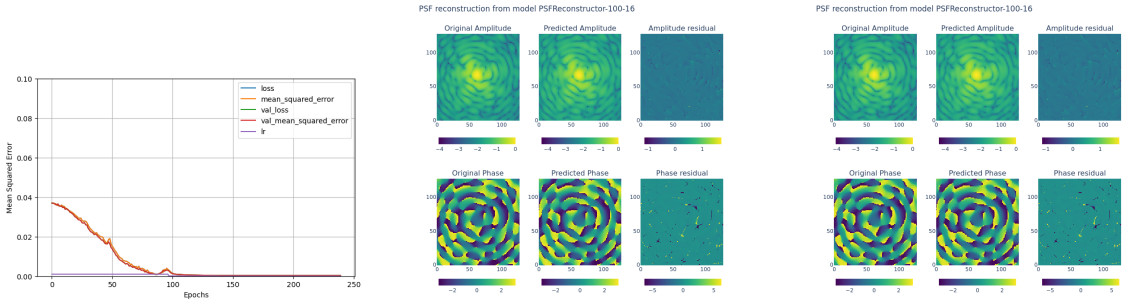
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [128, 128, 128, 128, 256,
          256, 512, 2000, 4000]
  -Regularizer: None
```

```
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 10000
  -Batch size: 16
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.0003098844608757645
```



(a) Training Evolution (b) Train datapoint (c) Train datapoint

Figure 23: Results of training the model PSFReconstructor-100-16-1

- Apart from the mse, no significant difference can be appreciated for different batch sizes using 100 datapoints.

- The goal for today is to study the correlation between the L2 norm of the pupil plane electric field and the L2 norm of the LP modes complex coefficients.

- First compute the L2 norm of the LP modes complex coefficients from the validation psf electric fields.

- Done!, here it is what it looks like

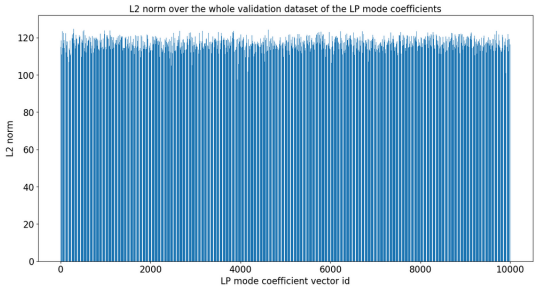


Figure 24: L2 norms for the overlap integral mode coefficients of the validation PSFs

- Let's do the same for the electric fields of the PSF
- Done!, here are the results:

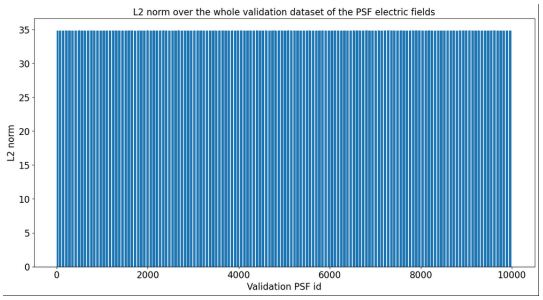


Figure 25: L2 norms of the validation PSFs electric fields

- After doing a correlation analysis the result is the following:
  `Pearson correlation coefficient:  0.1451513895198259`
  Which means that there is no correlation

---

06 March 2024

- Today I will be looking at the code from the `lantern_fiber_utils.py` file looking for the place where the LP mode coefficients are normalized

- Found it, in the function `make_fiber_modes()` used to compute de coefficients, there is a parameter called `normtosum` that is set to True by default, it looks as it normalizes the coefficients after the overlap integral is computed.

- Set `normtosum` to False, and compute 10000 output fluxes.

---

07 March 2024

- I will test a model with the new generated unnormalized output fluxes

---

EXPERIMENT UnnormalizedCoefficients-1

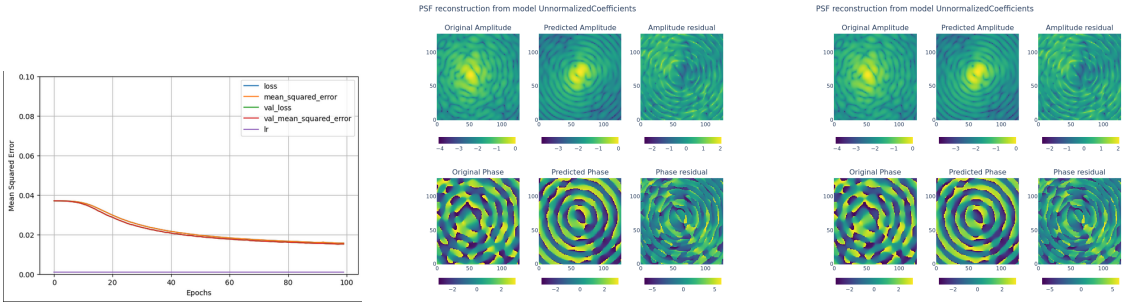
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [256, 256, 256]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
```

```
  -Dropout: False, 0.2


*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE


*TRAINING HYPERPARAMETERS:
  -Epochs: 100
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
  *RESULTS:
      -Train MSE: 0.01565057598054409
```



(a) Training Evolution (b) Train datapoint (c) Train datapoint

Figure 26: Results of training the model UnnormalizedCoefficientsS-1

- Looks like the problem with the data was in the normalization of the coefficients, I will reprocess the output fluxes again and then test with a bigger dataset.

- While, the processing is running I create two new functions to plot, amplitude-phase-intensity and output flux of the PL.

---

08 March 2024

- FUCK, When processing the data I forgot to disable the `normtosum` variable. Have to repeat the process again

---

11 March 2024

- Finally got the output fluxes from the unnormalized mode coefficients

---

EXPERIMENT PSFRecontructorFC10000-1

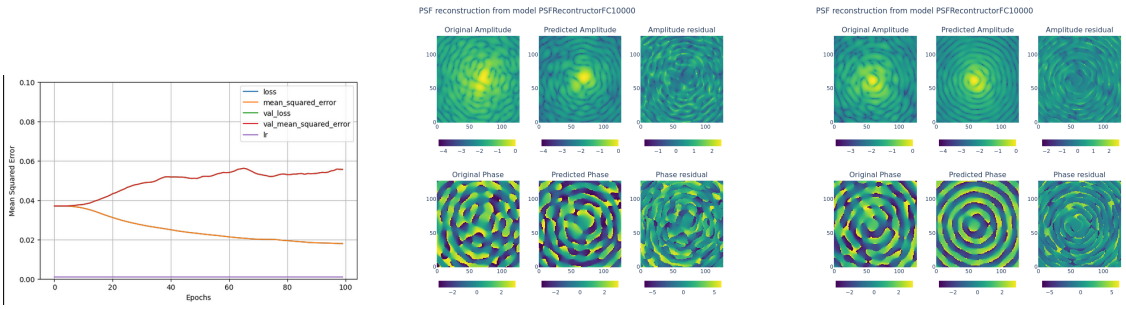
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [256, 256, 256]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 100
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
  *RESULTS:
```

```
        -Train MSE: 0.017938978970050812
        -Validation MSE: 0.055591899901628494
```



(a) Training Evolution (b) Validation datapoint (c) Train datapoint

Figure 27: Results of training the model PSFRecontructorFC10000-1

EXPERIMENT PSFRecontructorFC30000-1

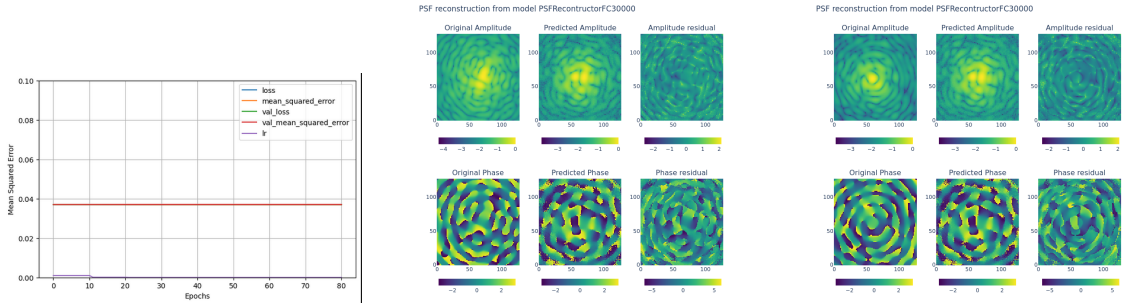
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [256, 256, 256]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
```

```
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 100
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
  *RESULTS:
      -Train MSE: 0.03696389123797417
      -Validation MSE: 0.03704820200800896
```



(a) Training Evolution (b) Validation datapoint (c) Train datapoint

Figure 28: Results of training the model PSFRecontructorFC30000-1

- Again, flatline, and same output for any input. I will try with all the train dataset and then start using different batch sizes, see how this works

---

EXPERIMENT PSFRecontructorFC70000-1

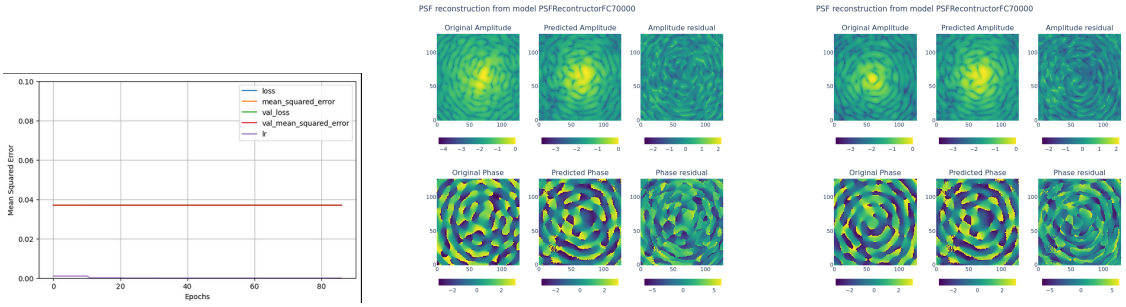
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [256, 256, 256]
  -Regularizer: None
  -Hidden Layers Activation: relu
```

```
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 100
  -Batch size: 64
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
  *RESULTS:
      -Train MSE: 0.03700976073741913
      -Validation MSE: 0.0370212197303772
```



(a) Training Evolution (b) Validation datapoint (c) Train datapoint

Figure 29: Results of training the model PSFRecontructorFC70000-1

- Batch size for these experiments is 64, maybe it is too big , let's try with 32

EXPERIMENT PSFRecontructorFC10000-32-1

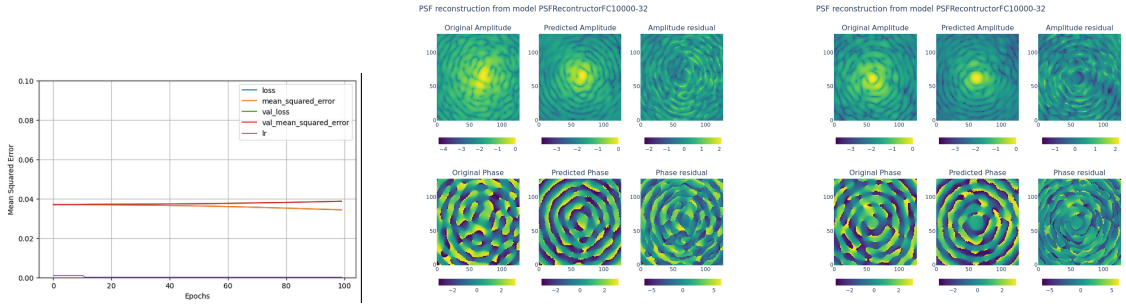
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [256, 256, 256]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
```

```
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 100
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
  *RESULTS:
      -Train MSE: 0.03432031720876694
      -Validation MSE: 0.038697339594364166
```



(a) Training Evolution (b) Validation datapoint (c) Train datapoint

Figure 30: Results of training the model PSFRecontructorFC10000-32-1

- Interesting, slower convergence but less overfitting

EXPERIMENT PSFRecontructorFC30000-32-1

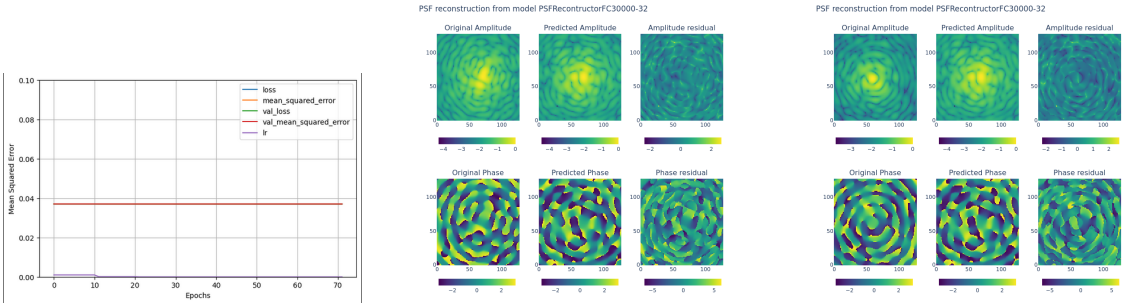
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [256, 256, 256]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
```

```
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 100
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
  *RESULTS:
      -Train MSE: 0.03701305016875267
      -Validation MSE: 0.03701600059866905
```



(a) Training Evolution (b) Validation datapoint (c) Train datapoint

Figure 31: Results of training the model PSFRecontructorFC30000-32-1

EXPERIMENT PSFRecontructorFC70000-32-1

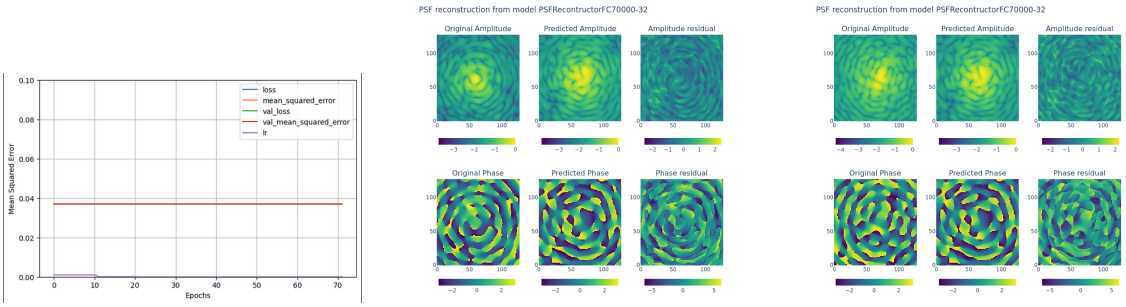
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [256, 256, 256]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2
```

```
*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 100
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 10 x0.1
    -Early Stop: MSE 25
```

VISUALIZATION:

```
  *RESULTS:
      -Train MSE: 0.037016756832599 64
      -Validation MSE: 0.037016723304986954
```



(a) Training Evolution (b) Validation datapoint (c) Train datapoint

Figure 32: Results of training the model PSFRecontructorFC70000-32-1

- So no good results, what I saw is that the lower the batch size, the longer it takes to coverge. Options now are:
  - Bigger NN
  - Bigger Batch size
  - Longer training

  I will start with 10000 datapoints and a bigger NN

EXPERIMENT PSFRecontructorBigFC10000-32-1

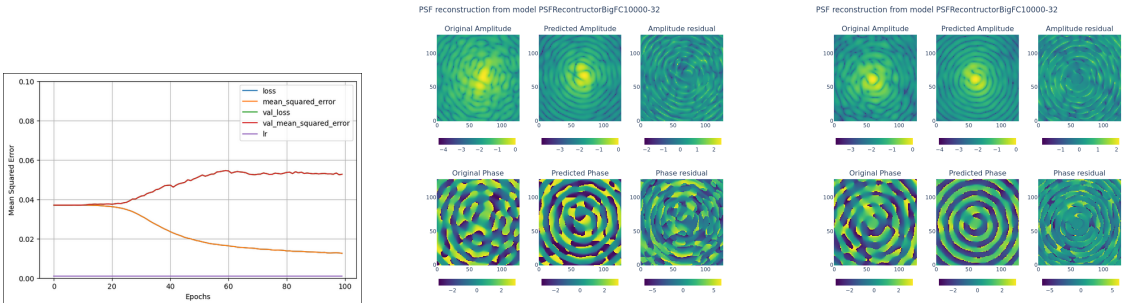
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [256, 256, 256, 256, 256, 256]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2
```

```
*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 100
  -Batch size: 32
  -Callbacks:
    -ReduceLROnPlateau: MSE 20 x0.1
    -Early Stop: MSE 50
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.012548761442303658
      -Validation MSE: 0.0527174137532711
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 33: Results of training the model psf-PSFRecontructorBigFC10000-32-1

EXPERIMENT PSFRecontructorBigFC30000-32-1

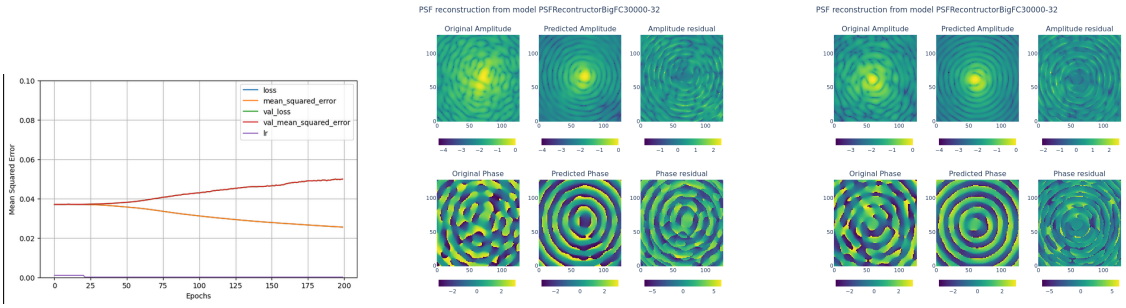
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [256, 256, 256, 256, 256, 256]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 200
  -Batch size: 32
```

```
  -Callbacks:
    -ReduceLROnPlateau: MSE 20 x0.1
    -Early Stop: MSE 50
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.025507930666208267
      -Validation MSE: 0.04988955706357956
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 34: Results of training the model PSFRecontructorBigFC30000-32-1

- With respect to the last to experiments, a bigger neural network seems to work better, with more datapoints the learning is delayed a bit, and the overfitting slightly improves, let's check with 70000 datapoints.

12 March 2024

EXPERIMENT PSFRecontructorBigFC70000-32-1

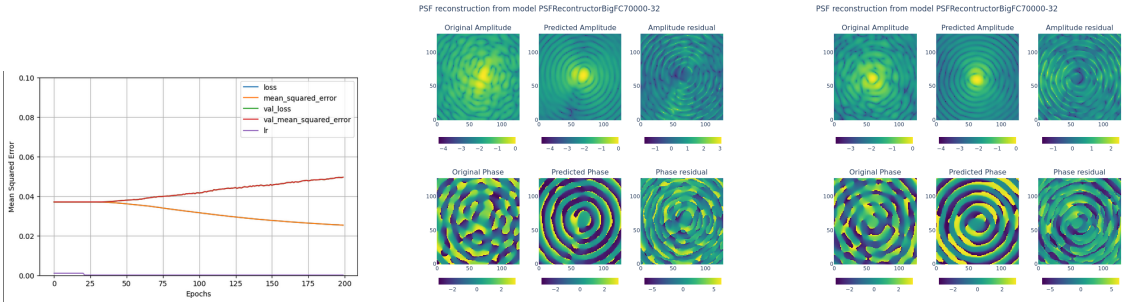
HYPERPARAMETERS:

```
*ARCHITECTURE HYPERPARAMETERS:
  -Fully Connected
  -Input shape: 19
  -Output shape: 32768
  -Hidden layers: [256, 256, 256, 256, 256, 256]
  -Regularizer: None
  -Hidden Layers Activation: relu
  -Output Layer Activation: linear
  -Batch Normalization: False
  -Dropout: False, 0.2

*COMPILATION HYPERPARAMETERS:
  -Optimizer: ADAM lr=0.001, beta_1=0.9, beta_2=0.999
  -Loss Function: MSE
  -Metric: MSE

*TRAINING HYPERPARAMETERS:
  -Epochs: 200
```

```
    -Batch size: 32
    -Callbacks:
      -ReduceLROnPlateau: MSE 20 x0.1
      -Early Stop: MSE 50
```

VISUALIZATION:

```
*RESULTS:
      -Train MSE: 0.025293584913015366
      -Validation MSE: 0.04955973103642464
```



(a) Training Evolution (b) Validation example (c) Train example

Figure 35: Results of training the model PSFRecontructorBigFC70000-32-1