Importing Libraries

In [1]:
```
%matplotlib inline
import os
import matplotlib.pyplot as plt
import pandas as pd
import numpy as np
import random
from importlib import reload
from tensorflow import keras
from keras.preprocessing.image import ImageDataGenerator
from keras.applications.resnet import ResNet50
from keras.layers import Flatten
from keras.layers import Dense
from keras.layers import Input
from keras.models import Model
from keras import backend as K
import tensorflow as tf
import glob
from shutil import copyfile
from keras.models import load_model
from keras import optimizers
```

Load the Resnet50 model from keras

In [2]:
```
img_shape = (224, 224, 3)
resnet_model = ResNet50(include_top=False, input_shape=img_shape) #Exclude the top Layer by adding include_top=False
```

Load the images and Preprocess the images

In [3]:
```
classes = [
    'Class1.1', 'Class1.2', 'Class1.3', 'Class2.1', 'Class2.2', 'Class3.1',
    'Class3.2', 'Class4.1', 'Class4.2', 'Class5.1', 'Class5.2', 'Class5.3',
    'Class5.4', 'Class6.1', 'Class6.2', 'Class7.1', 'Class7.2', 'Class7.3',
    'Class8.1', 'Class8.2', 'Class8.3', 'Class8.4', 'Class8.5', 'Class8.6',
    'Class8.7', 'Class9.1', 'Class9.2', 'Class9.3', 'Class10.1', 'Class10.2',
    'Class10.3', 'Class11.1', 'Class11.2', 'Class11.3', 'Class11.4',
    'Class11.5', 'Class11.6'
] #37 vectors of Galaxy Zoo divided into 11 classes based on the 11 different questions and their responses


def append_ext(fn):
    '''
    This function is used to take the GalaxyID from the CSV and append .jpg to it in order to denote the image names.
    '''
    return fn + ".jpg"


traindf = pd.read_csv('../Data/GalaxyZoo1/train/training_solutions_rev1.csv') #Read the Data Frame using pandas

traindf["id"] = traindf['GalaxyID'].astype(str).apply(append_ext) #Create a new column in the Data Frame called 'id' whi

datagenerator = ImageDataGenerator(
    fill_mode='nearest',
    cval=0,
    rescale=1/255,
    rotation_range=90,
    width_shift_range=0.1,
    height_shift_range=0.1,
    horizontal_flip=True,
    vertical_flip=True,
    validation_split=0.02)

train_generator = datagenerator.flow_from_dataframe(
    dataframe=traindf,
    directory="../Data/GalaxyZoo1/train/images_training_rev1/",
    x_col="id",
    y_col=classes,
    subset="training",
    batch_size=16,
    seed=123,
```

```
    shuffle=True,
    class_mode="raw",
    target_size=(224, 224))

validation_generator = datagenerator.flow_from_dataframe(
    dataframe=traindf,
    directory="../Data/GalaxyZoo1/train/images_training_rev1/",
    x_col="id",
    y_col=classes,
    subset="validation",
    batch_size=16,
    seed=123,
    shuffle=True,
    class_mode="raw",
    target_size=(224, 224))

STEP_SIZE_TRAIN = train_generator.n // train_generator.batch_size
STEP_SIZE_VALID = validation_generator.n // validation_generator.batch_size
```

```
Found 60347 validated image filenames.
Found 1231 validated image filenames.
```

In [4]:

```
# Flatten output of last layer before adding output layer (Dense layer)
x = Flatten()(resnet_model.output)

# Add output layer (number of outputs = 37)
x = Dense(len(classes), activation='sigmoid')(x)

# Load the modified model
model = Model(inputs=resnet_model.input, outputs=x)
```

In [5]:
```
print(model.summary())
```

```
Model: "model"
_________________________________________________________________________________________________
 Layer (type)                   Output Shape         Param #     Connected to
==================================================================================================
 input_1 (InputLayer)           [(None, 224, 224, 3  0           []
                                )]

 conv1_pad (ZeroPadding2D)      (None, 230, 230, 3)  0           ['input_1[0][0]']

 conv1_conv (Conv2D)            (None, 112, 112, 64  9472        ['conv1_pad[0][0]']
                                )

 conv1_bn (BatchNormalization)  (None, 112, 112, 64  256         ['conv1_conv[0][0]']
                                )

 conv1_relu (Activation)        (None, 112, 112, 64  0           ['conv1_bn[0][0]']
                                )

 pool1_pad (ZeroPadding2D)      (None, 114, 114, 64  0           ['conv1_relu[0][0]']
                                )

 pool1_pool (MaxPooling2D)      (None, 56, 56, 64)   0           ['pool1_pad[0][0]']

 conv2_block1_1_conv (Conv2D)   (None, 56, 56, 64)   4160        ['pool1_pool[0][0]']

 conv2_block1_1_bn (BatchNormal  (None, 56, 56, 64)  256         ['conv2_block1_1_conv[0][0]']
 ization)

 conv2_block1_1_relu (Activatio  (None, 56, 56, 64)  0           ['conv2_block1_1_bn[0][0]']
 n)

 conv2_block1_2_conv (Conv2D)   (None, 56, 56, 64)   36928       ['conv2_block1_1_relu[0][0]']

 conv2_block1_2_bn (BatchNormal  (None, 56, 56, 64)  256         ['conv2_block1_2_conv[0][0]']
 ization)

 conv2_block1_2_relu (Activatio  (None, 56, 56, 64)  0           ['conv2_block1_2_bn[0][0]']
 n)
```

```
conv2_block1_0_conv (Conv2D)   (None, 56, 56, 256)  16640       ['pool1_pool[0][0]']

conv2_block1_3_conv (Conv2D)   (None, 56, 56, 256)  16640       ['conv2_block1_2_relu[0][0]']

conv2_block1_0_bn (BatchNormal  (None, 56, 56, 256)  1024       ['conv2_block1_0_conv[0][0]']
ization)

conv2_block1_3_bn (BatchNormal  (None, 56, 56, 256)  1024       ['conv2_block1_3_conv[0][0]']
ization)

conv2_block1_add (Add)         (None, 56, 56, 256)  0           ['conv2_block1_0_bn[0][0]',
                                                                 'conv2_block1_3_bn[0][0]']

conv2_block1_out (Activation)  (None, 56, 56, 256)  0           ['conv2_block1_add[0][0]']

conv2_block2_1_conv (Conv2D)   (None, 56, 56, 64)   16448       ['conv2_block1_out[0][0]']

conv2_block2_1_bn (BatchNormal  (None, 56, 56, 64)  256         ['conv2_block2_1_conv[0][0]']
ization)

conv2_block2_1_relu (Activatio  (None, 56, 56, 64)  0           ['conv2_block2_1_bn[0][0]']
n)

conv2_block2_2_conv (Conv2D)   (None, 56, 56, 64)   36928       ['conv2_block2_1_relu[0][0]']

conv2_block2_2_bn (BatchNormal  (None, 56, 56, 64)  256         ['conv2_block2_2_conv[0][0]']
ization)

conv2_block2_2_relu (Activatio  (None, 56, 56, 64)  0           ['conv2_block2_2_bn[0][0]']
n)

conv2_block2_3_conv (Conv2D)   (None, 56, 56, 256)  16640       ['conv2_block2_2_relu[0][0]']

conv2_block2_3_bn (BatchNormal  (None, 56, 56, 256)  1024       ['conv2_block2_3_conv[0][0]']
ization)

conv2_block2_add (Add)         (None, 56, 56, 256)  0           ['conv2_block1_out[0][0]',
                                                                 'conv2_block2_3_bn[0][0]']

conv2_block2_out (Activation)  (None, 56, 56, 256)  0           ['conv2_block2_add[0][0]']

conv2_block3_1_conv (Conv2D)   (None, 56, 56, 64)   16448       ['conv2_block2_out[0][0]']
```

```
conv2_block3_1_bn (BatchNormal  (None, 56, 56, 64)  256         ['conv2_block3_1_conv[0][0]']
ization)


conv2_block3_1_relu (Activatio  (None, 56, 56, 64)  0           ['conv2_block3_1_bn[0][0]']
n)

conv2_block3_2_conv (Conv2D)   (None, 56, 56, 64)   36928       ['conv2_block3_1_relu[0][0]']

conv2_block3_2_bn (BatchNormal  (None, 56, 56, 64)  256         ['conv2_block3_2_conv[0][0]']
ization)

conv2_block3_2_relu (Activatio  (None, 56, 56, 64)  0           ['conv2_block3_2_bn[0][0]']
n)

conv2_block3_3_conv (Conv2D)   (None, 56, 56, 256)  16640       ['conv2_block3_2_relu[0][0]']

conv2_block3_3_bn (BatchNormal  (None, 56, 56, 256)  1024       ['conv2_block3_3_conv[0][0]']
ization)

conv2_block3_add (Add)         (None, 56, 56, 256)  0           ['conv2_block2_out[0][0]',
                                                                 'conv2_block3_3_bn[0][0]']

conv2_block3_out (Activation)  (None, 56, 56, 256)  0           ['conv2_block3_add[0][0]']

conv3_block1_1_conv (Conv2D)   (None, 28, 28, 128)  32896       ['conv2_block3_out[0][0]']

conv3_block1_1_bn (BatchNormal  (None, 28, 28, 128)  512        ['conv3_block1_1_conv[0][0]']
ization)

conv3_block1_1_relu (Activatio  (None, 28, 28, 128)  0          ['conv3_block1_1_bn[0][0]']
n)

conv3_block1_2_conv (Conv2D)   (None, 28, 28, 128)  147584      ['conv3_block1_1_relu[0][0]']

conv3_block1_2_bn (BatchNormal  (None, 28, 28, 128)  512        ['conv3_block1_2_conv[0][0]']
ization)

conv3_block1_2_relu (Activatio  (None, 28, 28, 128)  0          ['conv3_block1_2_bn[0][0]']
n)
```

```
conv3_block1_0_conv (Conv2D)   (None, 28, 28, 512)  131584      ['conv2_block3_out[0][0]']

conv3_block1_3_conv (Conv2D)   (None, 28, 28, 512)  66048       ['conv3_block1_2_relu[0][0]']

conv3_block1_0_bn (BatchNormal  (None, 28, 28, 512)  2048       ['conv3_block1_0_conv[0][0]']
ization)

conv3_block1_3_bn (BatchNormal  (None, 28, 28, 512)  2048       ['conv3_block1_3_conv[0][0]']
ization)

conv3_block1_add (Add)         (None, 28, 28, 512)  0          ['conv3_block1_0_bn[0][0]',
                                                                 'conv3_block1_3_bn[0][0]']

conv3_block1_out (Activation)  (None, 28, 28, 512)  0          ['conv3_block1_add[0][0]']

conv3_block2_1_conv (Conv2D)   (None, 28, 28, 128)  65664       ['conv3_block1_out[0][0]']

conv3_block2_1_bn (BatchNormal  (None, 28, 28, 128)  512       ['conv3_block2_1_conv[0][0]']
ization)

conv3_block2_1_relu (Activatio  (None, 28, 28, 128)  0         ['conv3_block2_1_bn[0][0]']
n)

conv3_block2_2_conv (Conv2D)   (None, 28, 28, 128)  147584      ['conv3_block2_1_relu[0][0]']

conv3_block2_2_bn (BatchNormal  (None, 28, 28, 128)  512       ['conv3_block2_2_conv[0][0]']
ization)

conv3_block2_2_relu (Activatio  (None, 28, 28, 128)  0         ['conv3_block2_2_bn[0][0]']
n)

conv3_block2_3_conv (Conv2D)   (None, 28, 28, 512)  66048       ['conv3_block2_2_relu[0][0]']

conv3_block2_3_bn (BatchNormal  (None, 28, 28, 512)  2048       ['conv3_block2_3_conv[0][0]']
ization)

conv3_block2_add (Add)         (None, 28, 28, 512)  0          ['conv3_block1_out[0][0]',
                                                                 'conv3_block2_3_bn[0][0]']

conv3_block2_out (Activation)  (None, 28, 28, 512)  0          ['conv3_block2_add[0][0]']

conv3_block3_1_conv (Conv2D)   (None, 28, 28, 128)  65664       ['conv3_block2_out[0][0]']
```

```
conv3_block3_1_bn (BatchNormal  (None, 28, 28, 128)  512        ['conv3_block3_1_conv[0][0]']
ization)


conv3_block3_1_relu (Activatio  (None, 28, 28, 128)  0          ['conv3_block3_1_bn[0][0]']
n)

conv3_block3_2_conv (Conv2D)   (None, 28, 28, 128)  147584      ['conv3_block3_1_relu[0][0]']

conv3_block3_2_bn (BatchNormal  (None, 28, 28, 128)  512        ['conv3_block3_2_conv[0][0]']
ization)

conv3_block3_2_relu (Activatio  (None, 28, 28, 128)  0          ['conv3_block3_2_bn[0][0]']
n)

conv3_block3_3_conv (Conv2D)   (None, 28, 28, 512)  66048       ['conv3_block3_2_relu[0][0]']

conv3_block3_3_bn (BatchNormal  (None, 28, 28, 512)  2048       ['conv3_block3_3_conv[0][0]']
ization)

conv3_block3_add (Add)         (None, 28, 28, 512)  0          ['conv3_block2_out[0][0]',
                                                                 'conv3_block3_3_bn[0][0]']

conv3_block3_out (Activation)  (None, 28, 28, 512)  0          ['conv3_block3_add[0][0]']

conv3_block4_1_conv (Conv2D)   (None, 28, 28, 128)  65664       ['conv3_block3_out[0][0]']

conv3_block4_1_bn (BatchNormal  (None, 28, 28, 128)  512        ['conv3_block4_1_conv[0][0]']
ization)

conv3_block4_1_relu (Activatio  (None, 28, 28, 128)  0          ['conv3_block4_1_bn[0][0]']
n)

conv3_block4_2_conv (Conv2D)   (None, 28, 28, 128)  147584      ['conv3_block4_1_relu[0][0]']

conv3_block4_2_bn (BatchNormal  (None, 28, 28, 128)  512        ['conv3_block4_2_conv[0][0]']
ization)

conv3_block4_2_relu (Activatio  (None, 28, 28, 128)  0          ['conv3_block4_2_bn[0][0]']
n)
```

```
conv3_block4_3_conv (Conv2D)   (None, 28, 28, 512)  66048       ['conv3_block4_2_relu[0][0]']

conv3_block4_3_bn (BatchNormal  (None, 28, 28, 512)  2048       ['conv3_block4_3_conv[0][0]']
ization)

conv3_block4_add (Add)         (None, 28, 28, 512)  0           ['conv3_block3_out[0][0]',
                                                                 'conv3_block4_3_bn[0][0]']

conv3_block4_out (Activation)  (None, 28, 28, 512)  0           ['conv3_block4_add[0][0]']

conv4_block1_1_conv (Conv2D)   (None, 14, 14, 256)  131328      ['conv3_block4_out[0][0]']

conv4_block1_1_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block1_1_conv[0][0]']
ization)

conv4_block1_1_relu (Activatio  (None, 14, 14, 256)  0          ['conv4_block1_1_bn[0][0]']
n)

conv4_block1_2_conv (Conv2D)   (None, 14, 14, 256)  590080      ['conv4_block1_1_relu[0][0]']

conv4_block1_2_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block1_2_conv[0][0]']
ization)

conv4_block1_2_relu (Activatio  (None, 14, 14, 256)  0          ['conv4_block1_2_bn[0][0]']
n)

conv4_block1_0_conv (Conv2D)   (None, 14, 14, 1024  525312      ['conv3_block4_out[0][0]']
                               )

conv4_block1_3_conv (Conv2D)   (None, 14, 14, 1024  263168      ['conv4_block1_2_relu[0][0]']
                               )

conv4_block1_0_bn (BatchNormal  (None, 14, 14, 1024  4096       ['conv4_block1_0_conv[0][0]']
ization)                       )

conv4_block1_3_bn (BatchNormal  (None, 14, 14, 1024  4096       ['conv4_block1_3_conv[0][0]']
ization)                       )

conv4_block1_add (Add)         (None, 14, 14, 1024  0           ['conv4_block1_0_bn[0][0]',
                               )                                 'conv4_block1_3_bn[0][0]']
```

```
conv4_block1_out (Activation)  (None, 14, 14, 1024  0           ['conv4_block1_add[0][0]']
                               )

conv4_block2_1_conv (Conv2D)   (None, 14, 14, 256)  262400      ['conv4_block1_out[0][0]']


conv4_block2_1_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block2_1_conv[0][0]']
ization)

conv4_block2_1_relu (Activatio  (None, 14, 14, 256)  0          ['conv4_block2_1_bn[0][0]']
n)

conv4_block2_2_conv (Conv2D)   (None, 14, 14, 256)  590080      ['conv4_block2_1_relu[0][0]']

conv4_block2_2_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block2_2_conv[0][0]']
ization)

conv4_block2_2_relu (Activatio  (None, 14, 14, 256)  0          ['conv4_block2_2_bn[0][0]']
n)

conv4_block2_3_conv (Conv2D)   (None, 14, 14, 1024  263168      ['conv4_block2_2_relu[0][0]']
                               )

conv4_block2_3_bn (BatchNormal  (None, 14, 14, 1024  4096       ['conv4_block2_3_conv[0][0]']
ization)                       )

conv4_block2_add (Add)         (None, 14, 14, 1024  0           ['conv4_block1_out[0][0]',
                               )                                 'conv4_block2_3_bn[0][0]']

conv4_block2_out (Activation)  (None, 14, 14, 1024  0           ['conv4_block2_add[0][0]']
                               )

conv4_block3_1_conv (Conv2D)   (None, 14, 14, 256)  262400      ['conv4_block2_out[0][0]']

conv4_block3_1_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block3_1_conv[0][0]']
ization)

conv4_block3_1_relu (Activatio  (None, 14, 14, 256)  0          ['conv4_block3_1_bn[0][0]']
n)

conv4_block3_2_conv (Conv2D)   (None, 14, 14, 256)  590080      ['conv4_block3_1_relu[0][0]']
```

```
conv4_block3_2_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block3_2_conv[0][0]']
ization)

conv4_block3_2_relu (Activatio  (None, 14, 14, 256)  0         ['conv4_block3_2_bn[0][0]']
n)

conv4_block3_3_conv (Conv2D)   (None, 14, 14, 1024  263168      ['conv4_block3_2_relu[0][0]']
                               )

conv4_block3_3_bn (BatchNormal  (None, 14, 14, 1024  4096       ['conv4_block3_3_conv[0][0]']
ization)                       )

conv4_block3_add (Add)         (None, 14, 14, 1024  0          ['conv4_block2_out[0][0]',
                               )                                 'conv4_block3_3_bn[0][0]']

conv4_block3_out (Activation)  (None, 14, 14, 1024  0          ['conv4_block3_add[0][0]']
                               )

conv4_block4_1_conv (Conv2D)   (None, 14, 14, 256)  262400     ['conv4_block3_out[0][0]']

conv4_block4_1_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block4_1_conv[0][0]']
ization)

conv4_block4_1_relu (Activatio  (None, 14, 14, 256)  0         ['conv4_block4_1_bn[0][0]']
n)

conv4_block4_2_conv (Conv2D)   (None, 14, 14, 256)  590080     ['conv4_block4_1_relu[0][0]']

conv4_block4_2_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block4_2_conv[0][0]']
ization)

conv4_block4_2_relu (Activatio  (None, 14, 14, 256)  0         ['conv4_block4_2_bn[0][0]']
n)

conv4_block4_3_conv (Conv2D)   (None, 14, 14, 1024  263168      ['conv4_block4_2_relu[0][0]']
                               )

conv4_block4_3_bn (BatchNormal  (None, 14, 14, 1024  4096       ['conv4_block4_3_conv[0][0]']
ization)                       )

conv4_block4_add (Add)         (None, 14, 14, 1024  0          ['conv4_block3_out[0][0]',
                               )                                 'conv4_block4_3_bn[0][0]']
```

```
conv4_block4_out (Activation)  (None, 14, 14, 1024  0           ['conv4_block4_add[0][0]']
                               )


conv4_block5_1_conv (Conv2D)   (None, 14, 14, 256)  262400      ['conv4_block4_out[0][0]']

conv4_block5_1_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block5_1_conv[0][0]']
ization)

conv4_block5_1_relu (Activatio  (None, 14, 14, 256)  0          ['conv4_block5_1_bn[0][0]']
n)

conv4_block5_2_conv (Conv2D)   (None, 14, 14, 256)  590080      ['conv4_block5_1_relu[0][0]']

conv4_block5_2_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block5_2_conv[0][0]']
ization)

conv4_block5_2_relu (Activatio  (None, 14, 14, 256)  0          ['conv4_block5_2_bn[0][0]']
n)

conv4_block5_3_conv (Conv2D)   (None, 14, 14, 1024  263168      ['conv4_block5_2_relu[0][0]']
                               )

conv4_block5_3_bn (BatchNormal  (None, 14, 14, 1024  4096       ['conv4_block5_3_conv[0][0]']
ization)                       )

conv4_block5_add (Add)         (None, 14, 14, 1024  0           ['conv4_block4_out[0][0]',
                               )                                 'conv4_block5_3_bn[0][0]']

conv4_block5_out (Activation)  (None, 14, 14, 1024  0           ['conv4_block5_add[0][0]']
                               )

conv4_block6_1_conv (Conv2D)   (None, 14, 14, 256)  262400      ['conv4_block5_out[0][0]']

conv4_block6_1_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block6_1_conv[0][0]']
ization)

conv4_block6_1_relu (Activatio  (None, 14, 14, 256)  0          ['conv4_block6_1_bn[0][0]']
n)

conv4_block6_2_conv (Conv2D)   (None, 14, 14, 256)  590080      ['conv4_block6_1_relu[0][0]']
```

```
conv4_block6_2_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block6_2_conv[0][0]']
ization)

conv4_block6_2_relu (Activatio  (None, 14, 14, 256)  0          ['conv4_block6_2_bn[0][0]']
n)

conv4_block6_3_conv (Conv2D)   (None, 14, 14, 1024  263168      ['conv4_block6_2_relu[0][0]']
                               )

conv4_block6_3_bn (BatchNormal  (None, 14, 14, 1024  4096       ['conv4_block6_3_conv[0][0]']
ization)                       )

conv4_block6_add (Add)         (None, 14, 14, 1024  0          ['conv4_block5_out[0][0]',
                               )                                 'conv4_block6_3_bn[0][0]']

conv4_block6_out (Activation)  (None, 14, 14, 1024  0          ['conv4_block6_add[0][0]']
                               )

conv5_block1_1_conv (Conv2D)   (None, 7, 7, 512)    524800     ['conv4_block6_out[0][0]']

conv5_block1_1_bn (BatchNormal  (None, 7, 7, 512)   2048       ['conv5_block1_1_conv[0][0]']
ization)

conv5_block1_1_relu (Activatio  (None, 7, 7, 512)   0          ['conv5_block1_1_bn[0][0]']
n)

conv5_block1_2_conv (Conv2D)   (None, 7, 7, 512)    2359808    ['conv5_block1_1_relu[0][0]']

conv5_block1_2_bn (BatchNormal  (None, 7, 7, 512)   2048       ['conv5_block1_2_conv[0][0]']
ization)

conv5_block1_2_relu (Activatio  (None, 7, 7, 512)   0          ['conv5_block1_2_bn[0][0]']
n)

conv5_block1_0_conv (Conv2D)   (None, 7, 7, 2048)   2099200    ['conv4_block6_out[0][0]']

conv5_block1_3_conv (Conv2D)   (None, 7, 7, 2048)   1050624    ['conv5_block1_2_relu[0][0]']

conv5_block1_0_bn (BatchNormal  (None, 7, 7, 2048)  8192       ['conv5_block1_0_conv[0][0]']
ization)
```

```
conv5_block1_3_bn (BatchNormal  (None, 7, 7, 2048)  8192        ['conv5_block1_3_conv[0][0]']
ization)

conv5_block1_add (Add)         (None, 7, 7, 2048)   0           ['conv5_block1_0_bn[0][0]',

                                                                 'conv5_block1_3_bn[0][0]']

conv5_block1_out (Activation)  (None, 7, 7, 2048)   0           ['conv5_block1_add[0][0]']

conv5_block2_1_conv (Conv2D)   (None, 7, 7, 512)    1049088     ['conv5_block1_out[0][0]']

conv5_block2_1_bn (BatchNormal  (None, 7, 7, 512)   2048        ['conv5_block2_1_conv[0][0]']
ization)

conv5_block2_1_relu (Activatio  (None, 7, 7, 512)   0           ['conv5_block2_1_bn[0][0]']
n)

conv5_block2_2_conv (Conv2D)   (None, 7, 7, 512)    2359808     ['conv5_block2_1_relu[0][0]']

conv5_block2_2_bn (BatchNormal  (None, 7, 7, 512)   2048        ['conv5_block2_2_conv[0][0]']
ization)

conv5_block2_2_relu (Activatio  (None, 7, 7, 512)   0           ['conv5_block2_2_bn[0][0]']
n)

conv5_block2_3_conv (Conv2D)   (None, 7, 7, 2048)   1050624     ['conv5_block2_2_relu[0][0]']

conv5_block2_3_bn (BatchNormal  (None, 7, 7, 2048)  8192        ['conv5_block2_3_conv[0][0]']
ization)

conv5_block2_add (Add)         (None, 7, 7, 2048)   0           ['conv5_block1_out[0][0]',
                                                                 'conv5_block2_3_bn[0][0]']

conv5_block2_out (Activation)  (None, 7, 7, 2048)   0           ['conv5_block2_add[0][0]']

conv5_block3_1_conv (Conv2D)   (None, 7, 7, 512)    1049088     ['conv5_block2_out[0][0]']

conv5_block3_1_bn (BatchNormal  (None, 7, 7, 512)   2048        ['conv5_block3_1_conv[0][0]']
ization)

conv5_block3_1_relu (Activatio  (None, 7, 7, 512)   0           ['conv5_block3_1_bn[0][0]']
```

```
n)

conv5_block3_2_conv (Conv2D)   (None, 7, 7, 512)    2359808     ['conv5_block3_1_relu[0][0]']

conv5_block3_2_bn (BatchNormal  (None, 7, 7, 512)   2048        ['conv5_block3_2_conv[0][0]']
ization)

conv5_block3_2_relu (Activatio  (None, 7, 7, 512)   0           ['conv5_block3_2_bn[0][0]']
n)

conv5_block3_3_conv (Conv2D)   (None, 7, 7, 2048)   1050624     ['conv5_block3_2_relu[0][0]']

conv5_block3_3_bn (BatchNormal  (None, 7, 7, 2048)  8192        ['conv5_block3_3_conv[0][0]']
ization)

conv5_block3_add (Add)         (None, 7, 7, 2048)   0           ['conv5_block2_out[0][0]',
                                                                 'conv5_block3_3_bn[0][0]']

conv5_block3_out (Activation)  (None, 7, 7, 2048)   0           ['conv5_block3_add[0][0]']

flatten (Flatten)              (None, 100352)       0           ['conv5_block3_out[0][0]']

dense (Dense)                  (None, 37)           3713061     ['flatten[0][0]']

==================================================================================================
Total params: 27,300,773
Trainable params: 27,247,653
Non-trainable params: 53,120
__________________________________________________________________________________________________
None
```

In [6]:

```
for layer in model.layers:
    layer.trainable = True

optimizer = keras.optimizers.Adam(learning_rate=0.001, decay=5e-4)

model.compile(optimizer, loss='mse', metrics=["accuracy"])
```

In [7]:
```
from keras.callbacks import Callback
from keras.callbacks import ModelCheckpoint, Callback, EarlyStopping


class LossHistory(Callback):
    def on_train_begin(self, logs={}):
        self.losses = []
        self.val_losses = []

    def on_batch_end(self, batch, logs={}):
        self.losses.append(logs.get('loss'))
        self.val_losses.append(logs.get('val_loss'))


early_stopping = EarlyStopping(
    monitor='val_loss', patience=4, verbose=1, mode='auto')

history = LossHistory()

from keras.callbacks import ModelCheckpoint
checkpointer = ModelCheckpoint(
    filepath='../../weights.hdf5', verbose=2, save_best_only=True)
```

In [8]:
```
hist = model.fit(
    train_generator,
    steps_per_epoch=STEP_SIZE_TRAIN,
    validation_data=validation_generator,
    validation_steps=STEP_SIZE_VALID,
    epochs=30,
    callbacks=[history, checkpointer, early_stopping])
```

```
Epoch 1/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0454 - accuracy: 0.3113
Epoch 1: val_loss improved from inf to 0.02185, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 2504s 662ms/step - loss: 0.0454 - accuracy: 0.3113 - val_loss: 0.0218 - va
l_accuracy: 0.6086
Epoch 2/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0217 - accuracy: 0.5759
Epoch 2: val_loss improved from 0.02185 to 0.01868, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1002s 266ms/step - loss: 0.0217 - accuracy: 0.5759 - val_loss: 0.0187 - va
l_accuracy: 0.6554
Epoch 3/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0204 - accuracy: 0.6179
Epoch 3: val_loss improved from 0.01868 to 0.01702, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1003s 266ms/step - loss: 0.0204 - accuracy: 0.6179 - val_loss: 0.0170 - va
l_accuracy: 0.6719
Epoch 4/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0187 - accuracy: 0.6640
Epoch 4: val_loss improved from 0.01702 to 0.01674, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1004s 266ms/step - loss: 0.0187 - accuracy: 0.6640 - val_loss: 0.0167 - va
l_accuracy: 0.7163
Epoch 5/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0172 - accuracy: 0.6951
Epoch 5: val_loss improved from 0.01674 to 0.01460, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1031s 273ms/step - loss: 0.0172 - accuracy: 0.6951 - val_loss: 0.0146 - va
l_accuracy: 0.7237
Epoch 6/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0166 - accuracy: 0.6913
Epoch 6: val_loss did not improve from 0.01460
3771/3771 [==============================] - 1003s 266ms/step - loss: 0.0166 - accuracy: 0.6913 - val_loss: 0.0169 - va
l_accuracy: 0.6382
Epoch 7/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0157 - accuracy: 0.7134
Epoch 7: val_loss did not improve from 0.01460
```

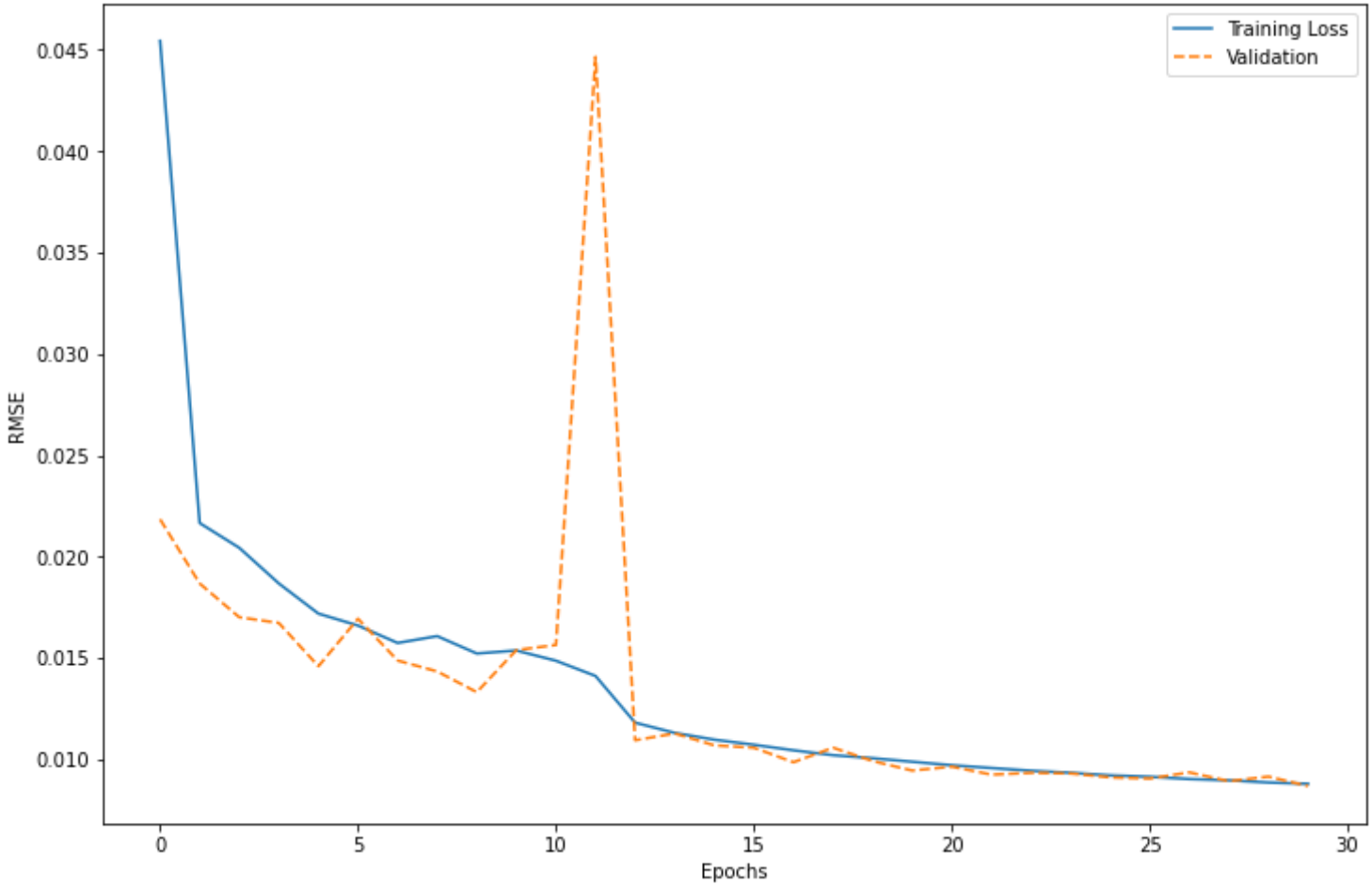
```
3771/3771 [==============================] - 1004s 266ms/step - loss: 0.0157 - accuracy: 0.7134 - val_loss: 0.0149 - va
l_accuracy: 0.7352
Epoch 8/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0161 - accuracy: 0.7092
Epoch 8: val_loss improved from 0.01460 to 0.01434, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1007s 267ms/step - loss: 0.0161 - accuracy: 0.7092 - val_loss: 0.0143 - va
l_accuracy: 0.7566
Epoch 9/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0152 - accuracy: 0.7257
Epoch 9: val_loss improved from 0.01434 to 0.01332, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1012s 268ms/step - loss: 0.0152 - accuracy: 0.7257 - val_loss: 0.0133 - va
l_accuracy: 0.7451
Epoch 10/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0154 - accuracy: 0.7227
Epoch 10: val_loss did not improve from 0.01332
3771/3771 [==============================] - 1005s 266ms/step - loss: 0.0154 - accuracy: 0.7227 - val_loss: 0.0154 - va
l_accuracy: 0.7360
Epoch 11/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0149 - accuracy: 0.7082
Epoch 11: val_loss did not improve from 0.01332
3771/3771 [==============================] - 1004s 266ms/step - loss: 0.0149 - accuracy: 0.7082 - val_loss: 0.0156 - va
l_accuracy: 0.6546
Epoch 12/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0141 - accuracy: 0.7069
Epoch 12: val_loss did not improve from 0.01332
3771/3771 [==============================] - 1005s 267ms/step - loss: 0.0141 - accuracy: 0.7069 - val_loss: 0.0447 - va
l_accuracy: 0.2804
Epoch 13/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0118 - accuracy: 0.7523
Epoch 13: val_loss improved from 0.01332 to 0.01095, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1008s 267ms/step - loss: 0.0118 - accuracy: 0.7523 - val_loss: 0.0109 - va
l_accuracy: 0.7780
Epoch 14/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0113 - accuracy: 0.7597
Epoch 14: val_loss did not improve from 0.01095
3771/3771 [==============================] - 1006s 267ms/step - loss: 0.0113 - accuracy: 0.7597 - val_loss: 0.0113 - va
l_accuracy: 0.7895
Epoch 15/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0110 - accuracy: 0.7648
Epoch 15: val_loss improved from 0.01095 to 0.01070, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1006s 267ms/step - loss: 0.0110 - accuracy: 0.7648 - val_loss: 0.0107 - va
l_accuracy: 0.7969
```

```
Epoch 16/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0107 - accuracy: 0.7712
Epoch 16: val_loss improved from 0.01070 to 0.01058, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1007s 267ms/step - loss: 0.0107 - accuracy: 0.7712 - val_loss: 0.0106 - va
l_accuracy: 0.7755
Epoch 17/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0105 - accuracy: 0.7734
Epoch 17: val_loss improved from 0.01058 to 0.00987, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1008s 267ms/step - loss: 0.0105 - accuracy: 0.7734 - val_loss: 0.0099 - va
l_accuracy: 0.7837
Epoch 18/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0102 - accuracy: 0.7769
Epoch 18: val_loss did not improve from 0.00987
3771/3771 [==============================] - 1006s 267ms/step - loss: 0.0102 - accuracy: 0.7769 - val_loss: 0.0106 - va
l_accuracy: 0.7887
Epoch 19/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0101 - accuracy: 0.7785
Epoch 19: val_loss did not improve from 0.00987
3771/3771 [==============================] - 1006s 267ms/step - loss: 0.0101 - accuracy: 0.7785 - val_loss: 0.0099 - va
l_accuracy: 0.7985
Epoch 20/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0099 - accuracy: 0.7830
Epoch 20: val_loss improved from 0.00987 to 0.00945, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1008s 267ms/step - loss: 0.0099 - accuracy: 0.7830 - val_loss: 0.0095 - va
l_accuracy: 0.7780
Epoch 21/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0097 - accuracy: 0.7829
Epoch 21: val_loss did not improve from 0.00945
3771/3771 [==============================] - 1007s 267ms/step - loss: 0.0097 - accuracy: 0.7829 - val_loss: 0.0096 - va
l_accuracy: 0.7854
Epoch 22/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0096 - accuracy: 0.7843
Epoch 22: val_loss improved from 0.00945 to 0.00925, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1007s 267ms/step - loss: 0.0096 - accuracy: 0.7843 - val_loss: 0.0093 - va
l_accuracy: 0.8109
Epoch 23/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0094 - accuracy: 0.7866
Epoch 23: val_loss did not improve from 0.00925
3771/3771 [==============================] - 1005s 266ms/step - loss: 0.0094 - accuracy: 0.7866 - val_loss: 0.0093 - va
l_accuracy: 0.7993
Epoch 24/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0093 - accuracy: 0.7874
```

```
Epoch 24: val_loss did not improve from 0.00925
3771/3771 [==============================] - 1006s 267ms/step - loss: 0.0093 - accuracy: 0.7874 - val_loss: 0.0093 - va
l_accuracy: 0.7788
Epoch 25/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0092 - accuracy: 0.7883
Epoch 25: val_loss improved from 0.00925 to 0.00912, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1009s 267ms/step - loss: 0.0092 - accuracy: 0.7883 - val_loss: 0.0091 - va
l_accuracy: 0.8092
Epoch 26/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0091 - accuracy: 0.7897
Epoch 26: val_loss improved from 0.00912 to 0.00906, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1010s 268ms/step - loss: 0.0091 - accuracy: 0.7897 - val_loss: 0.0091 - va
l_accuracy: 0.8117
Epoch 27/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0090 - accuracy: 0.7920
Epoch 27: val_loss did not improve from 0.00906
3771/3771 [==============================] - 1007s 267ms/step - loss: 0.0090 - accuracy: 0.7920 - val_loss: 0.0094 - va
l_accuracy: 0.8043

Epoch 28/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0090 - accuracy: 0.7958
Epoch 28: val_loss improved from 0.00906 to 0.00893, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1008s 267ms/step - loss: 0.0090 - accuracy: 0.7958 - val_loss: 0.0089 - va
l_accuracy: 0.8158
Epoch 29/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0089 - accuracy: 0.7928
Epoch 29: val_loss did not improve from 0.00893
3771/3771 [==============================] - 1005s 267ms/step - loss: 0.0089 - accuracy: 0.7928 - val_loss: 0.0092 - va
l_accuracy: 0.8117
Epoch 30/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0088 - accuracy: 0.7955
Epoch 30: val_loss improved from 0.00893 to 0.00869, saving model to ../..\weights.hdf5
3771/3771 [==============================] - 1008s 267ms/step - loss: 0.0088 - accuracy: 0.7955 - val_loss: 0.0087 - va
l_accuracy: 0.8100
```

In [9]:
```
plt.figure(figsize=(12, 8))
plt.plot(hist.epoch, hist.history['loss'], label='Training Loss')
plt.plot(
    hist.epoch, hist.history['val_loss'], label='Validation', linestyle='--')
plt.xlabel("Epochs")
plt.ylabel("RMSE")
plt.legend()
plt.show()
```



In [10]:
```
from keras.models import load_model

model = load_model('../../weights.hdf5')
```

In [22]:
```
test_datagenerator = ImageDataGenerator(rescale=1/255)

test_generator = test_datagenerator.flow_from_directory(
    directory="../Data/GalaxyZoo1/test/",
    classes=['images_test_rev1'],
    class_mode=None,
    color_mode="rgb",
    batch_size=1,
    target_size=(224, 224),
    seed=123,
    shuffle=False)
```

```
Found 79975 images belonging to 1 classes.
```

In [23]:
```
predictions = model.predict(
    test_generator,
    steps=test_generator.n/test_generator.batch_size,
    verbose=1)

print(predictions.shape)
```

```
79975/79975 [==============================] - 1146s 14ms/step
(79975, 37)
```