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.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
```

In [2]:
```
img_shape = (224, 224, 3)
model = load_model('../../weights.hdf5')
model
```

Out[2]:
```
<keras.engine.functional.Functional at 0x27a733717c0>
```

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/GalaxyZoo2/GZ_2_Processed_classes.csv')
traindf["id"] = traindf['GalaxyID'].astype(str).apply(append_ext)

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/GalaxyZoo2/images_gz2/images",
    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/GalaxyZoo2/images_gz2/images",
    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
```

```
D:\anaconda\envs\majorproject\lib\site-packages\keras\preprocessing\image.py:1267: UserWarning: Found 108 invalid image
filename(s) in x_col="id". These filename(s) will be ignored.
  warnings.warn('Found {} invalid image filename(s) in x_col="{}". '

Found 199651 validated image filenames.
Found 4074 validated image filenames.

D:\anaconda\envs\majorproject\lib\site-packages\keras\preprocessing\image.py:1267: UserWarning: Found 108 invalid image
filename(s) in x_col="id". These filename(s) will be ignored.
  warnings.warn('Found {} invalid image filename(s) in x_col="{}". '
```

In [4]:
```
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 [5]:

```
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 [6]:
```
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='../Data/GalaxyZoo2/model/IL_Weights.hdf5', verbose=2, save_best_only=True)
```

In [7]:
```
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
12478/12478 [==============================] - ETA: 0s - loss: 0.0526 - accuracy: 0.4540
Epoch 1: val_loss improved from inf to 0.03843, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 7002s 560ms/step - loss: 0.0526 - accuracy: 0.4540 - val_loss: 0.0384 -
val_accuracy: 0.4235
Epoch 2/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0488 - accuracy: 0.4422
Epoch 2: val_loss improved from 0.03843 to 0.03670, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 5867s 470ms/step - loss: 0.0488 - accuracy: 0.4422 - val_loss: 0.0367 -
val_accuracy: 0.3206
Epoch 3/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0478 - accuracy: 0.4382
Epoch 3: val_loss did not improve from 0.03670
12478/12478 [==============================] - 6114s 490ms/step - loss: 0.0478 - accuracy: 0.4382 - val_loss: 0.0369 -
val_accuracy: 0.4045
Epoch 4/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0473 - accuracy: 0.4328
Epoch 4: val_loss improved from 0.03670 to 0.03573, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 4774s 383ms/step - loss: 0.0473 - accuracy: 0.4328 - val_loss: 0.0357 -
val_accuracy: 0.3612
Epoch 5/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0469 - accuracy: 0.4326
Epoch 5: val_loss improved from 0.03573 to 0.03509, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 6346s 509ms/step - loss: 0.0469 - accuracy: 0.4326 - val_loss: 0.0351 -
val_accuracy: 0.3725
Epoch 6/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0466 - accuracy: 0.4277
Epoch 6: val_loss improved from 0.03509 to 0.03493, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 5739s 460ms/step - loss: 0.0466 - accuracy: 0.4277 - val_loss: 0.0349 -
val_accuracy: 0.3078
Epoch 7/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0465 - accuracy: 0.4287
Epoch 7: val_loss improved from 0.03493 to 0.03453, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
```

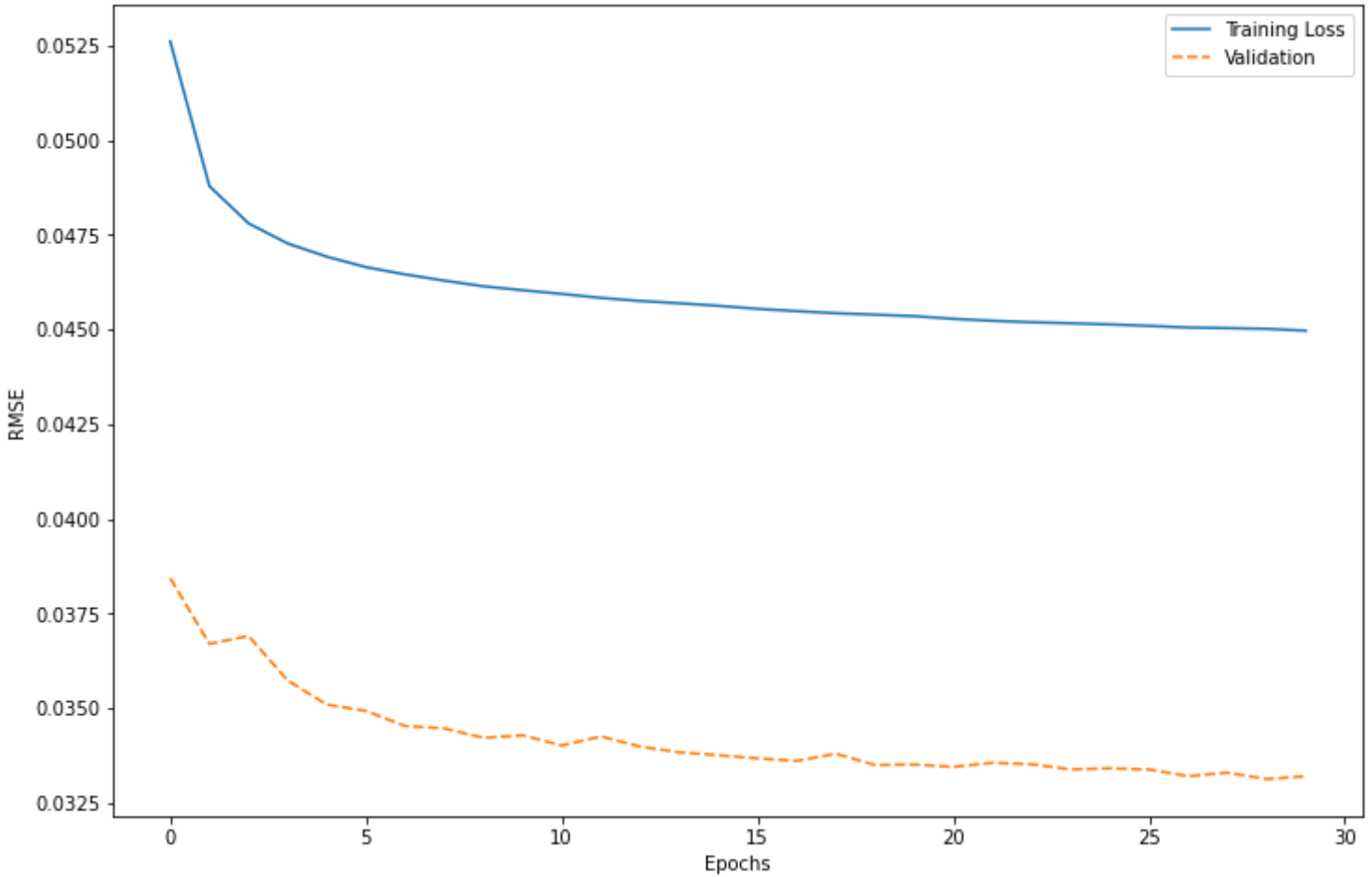
```
12478/12478 [==============================] - 4963s 397ms/step - loss: 0.0465 - accuracy: 0.4287 - val_loss: 0.0345 -
val_accuracy: 0.3314
Epoch 8/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0463 - accuracy: 0.4281
Epoch 8: val_loss improved from 0.03453 to 0.03447, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 6500s 521ms/step - loss: 0.0463 - accuracy: 0.4281 - val_loss: 0.0345 -
val_accuracy: 0.3056
Epoch 9/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0461 - accuracy: 0.4260
Epoch 9: val_loss improved from 0.03447 to 0.03422, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 7021s 563ms/step - loss: 0.0461 - accuracy: 0.4260 - val_loss: 0.0342 -
val_accuracy: 0.3484
Epoch 10/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0460 - accuracy: 0.4273
Epoch 10: val_loss did not improve from 0.03422
12478/12478 [==============================] - 5971s 479ms/step - loss: 0.0460 - accuracy: 0.4273 - val_loss: 0.0343 -
val_accuracy: 0.2872
Epoch 11/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0459 - accuracy: 0.4266
Epoch 11: val_loss improved from 0.03422 to 0.03402, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 3717s 298ms/step - loss: 0.0459 - accuracy: 0.4266 - val_loss: 0.0340 -
val_accuracy: 0.3221
Epoch 12/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0458 - accuracy: 0.4254
Epoch 12: val_loss did not improve from 0.03402
12478/12478 [==============================] - 4876s 391ms/step - loss: 0.0458 - accuracy: 0.4254 - val_loss: 0.0343 -
val_accuracy: 0.2987
Epoch 13/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0458 - accuracy: 0.4245
Epoch 13: val_loss improved from 0.03402 to 0.03399, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 4087s 328ms/step - loss: 0.0458 - accuracy: 0.4245 - val_loss: 0.0340 -
val_accuracy: 0.3209
Epoch 14/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0457 - accuracy: 0.4243
Epoch 14: val_loss improved from 0.03399 to 0.03384, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 4429s 355ms/step - loss: 0.0457 - accuracy: 0.4243 - val_loss: 0.0338 -
val_accuracy: 0.3366
Epoch 15/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0456 - accuracy: 0.4239
Epoch 15: val_loss improved from 0.03384 to 0.03376, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 6482s 519ms/step - loss: 0.0456 - accuracy: 0.4239 - val_loss: 0.0338 -
val_accuracy: 0.3553
```

```
Epoch 16/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0455 - accuracy: 0.4218
Epoch 16: val_loss improved from 0.03376 to 0.03368, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 5813s 466ms/step - loss: 0.0455 - accuracy: 0.4218 - val_loss: 0.0337 -
val_accuracy: 0.3386
Epoch 17/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0455 - accuracy: 0.4225
Epoch 17: val_loss improved from 0.03368 to 0.03361, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 6651s 533ms/step - loss: 0.0455 - accuracy: 0.4225 - val_loss: 0.0336 -
val_accuracy: 0.3174
Epoch 18/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0454 - accuracy: 0.4231
Epoch 18: val_loss did not improve from 0.03361
12478/12478 [==============================] - 3671s 294ms/step - loss: 0.0454 - accuracy: 0.4231 - val_loss: 0.0338 -
val_accuracy: 0.2970
Epoch 19/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0454 - accuracy: 0.4205
Epoch 19: val_loss improved from 0.03361 to 0.03350, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 4303s 345ms/step - loss: 0.0454 - accuracy: 0.4205 - val_loss: 0.0335 -
val_accuracy: 0.3250
Epoch 20/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0454 - accuracy: 0.4219
Epoch 20: val_loss did not improve from 0.03350
12478/12478 [==============================] - 7414s 594ms/step - loss: 0.0454 - accuracy: 0.4219 - val_loss: 0.0335 -
val_accuracy: 0.3219
Epoch 21/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0453 - accuracy: 0.4181
Epoch 21: val_loss improved from 0.03350 to 0.03345, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 5669s 454ms/step - loss: 0.0453 - accuracy: 0.4181 - val_loss: 0.0335 -
val_accuracy: 0.3182
Epoch 22/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0452 - accuracy: 0.4212
Epoch 22: val_loss did not improve from 0.03345
12478/12478 [==============================] - 5991s 480ms/step - loss: 0.0452 - accuracy: 0.4212 - val_loss: 0.0336 -
val_accuracy: 0.3014
Epoch 23/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0452 - accuracy: 0.4167
Epoch 23: val_loss did not improve from 0.03345
12478/12478 [==============================] - 4547s 364ms/step - loss: 0.0452 - accuracy: 0.4167 - val_loss: 0.0335 -
val_accuracy: 0.3029
Epoch 24/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0452 - accuracy: 0.4192
```

```
Epoch 24: val_loss improved from 0.03345 to 0.03338, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 3351s 269ms/step - loss: 0.0452 - accuracy: 0.4192 - val_loss: 0.0334 -
val_accuracy: 0.3091
Epoch 25/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0451 - accuracy: 0.4175
Epoch 25: val_loss did not improve from 0.03338
12478/12478 [==============================] - 4905s 393ms/step - loss: 0.0451 - accuracy: 0.4175 - val_loss: 0.0334 -
val_accuracy: 0.3027

Epoch 26/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0451 - accuracy: 0.4174
Epoch 26: val_loss improved from 0.03338 to 0.03338, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 4379s 351ms/step - loss: 0.0451 - accuracy: 0.4174 - val_loss: 0.0334 -
val_accuracy: 0.2918
Epoch 27/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0451 - accuracy: 0.4172
Epoch 27: val_loss improved from 0.03338 to 0.03321, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 3482s 279ms/step - loss: 0.0451 - accuracy: 0.4172 - val_loss: 0.0332 -
val_accuracy: 0.3152
Epoch 28/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0450 - accuracy: 0.4182
Epoch 28: val_loss did not improve from 0.03321
12478/12478 [==============================] - 3420s 274ms/step - loss: 0.0450 - accuracy: 0.4182 - val_loss: 0.0333 -
val_accuracy: 0.3164
Epoch 29/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0450 - accuracy: 0.4190
Epoch 29: val_loss improved from 0.03321 to 0.03313, saving model to ../Data/GalaxyZoo2/model\IL_Weights.hdf5
12478/12478 [==============================] - 3617s 290ms/step - loss: 0.0450 - accuracy: 0.4190 - val_loss: 0.0331 -
val_accuracy: 0.3174
Epoch 30/30
12478/12478 [==============================] - ETA: 0s - loss: 0.0450 - accuracy: 0.4163
Epoch 30: val_loss did not improve from 0.03313
12478/12478 [==============================] - 4685s 375ms/step - loss: 0.0450 - accuracy: 0.4163 - val_loss: 0.0332 -
val_accuracy: 0.3157
```

In [8]:
```
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 [ ]: