A Classification of Exoplanet Systems

By Liam Keeley

What is an **exoplanet**?

An **exoplanet** is a planet orbiting a star other than the sun

Exoplanets do not emit light

So they can be difficult to detect

Searching For Exoplanets

Doppler Wobbles

Jupiter (very large) sized planets in tight orbits around their sun cause their sun to wobble and cause repetitive doppler shifts: red-blue-red-blue-red

Eclipsing Systems

Tiny fluctuations in the light we receive from stars are caused by a planet coming between the earth and the observed star

Other Techniques

Proper Motions: sort of like Doppler Wobbles, but we observe the star moving in a circle instead of the shift

Infrared observation: planets do emit light, but only low energy light in the infrared part of the spectrum.

Gravitational microlensing: Use changes in gravitational lensing of super distant stars relative a closer star to predict the existence of a planet orbiting the closer star

Visual observation: couldn't we just see the planets? This would work by blocking out light from the stars so only the reflected light from planets is all that is left

Kepler Space Telescope Observations

- Designed to detect flux fluctuations (eclipsing systems) over larger periods of time
- Stares at stars for years
- Has successfully detected many exoplanets

Is there a criteria for a star system with one or more exoplanet?

Do these star systems share common characteristics?

Temperature?

Size?

Color?

Or something else?

If they do...

A ***Deep Learning*** model would be a good way to detect these shared characteristics

Which could be used to flag systems with a high likelihood of containing an exoplanet for future exploration

So That Is What I Made

Trained on data NASA published from their Kepler Space Telescope and seperate photos from the Sloan Digital Sky Survey (SDSS)

The Data

The NASA data contained the ra, dec, and annotations on whether the star had an exoplanet, as well as statistical info

SDSS images were deep space images, queried from coordinates within the field the Kepler Telescope observed

A typical image from the SDSS

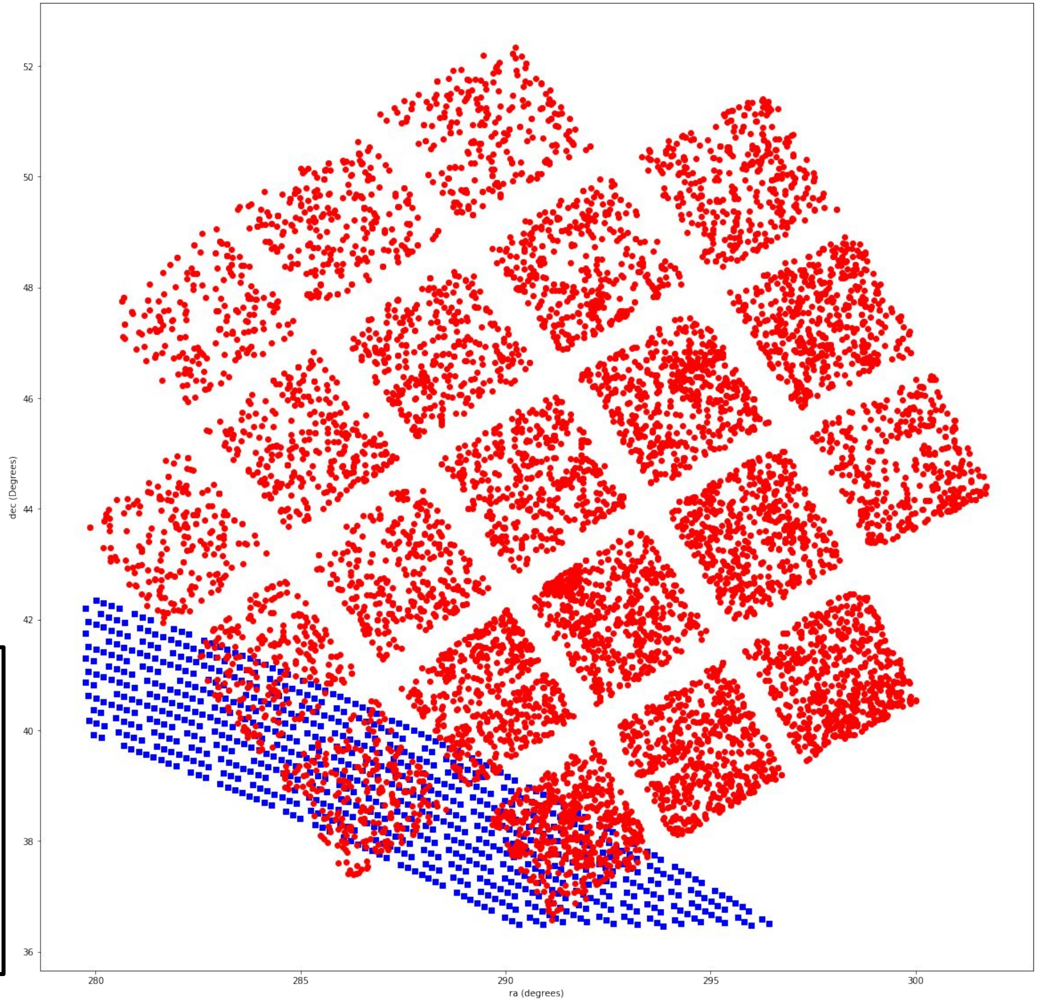
More Cool Pictures

Unfortunately...

The data from SDSS did not line up well with the data from the Kepler Mission

The red is coordinates for the stars in the Kepler Mission

The Blue is coordinates for the SDSS images



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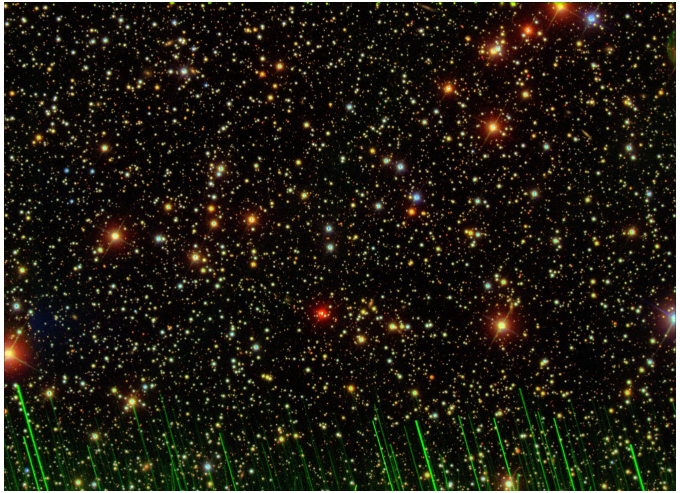
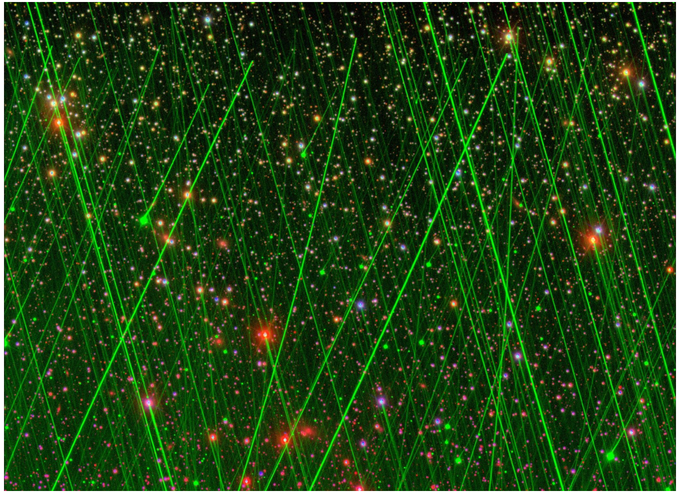


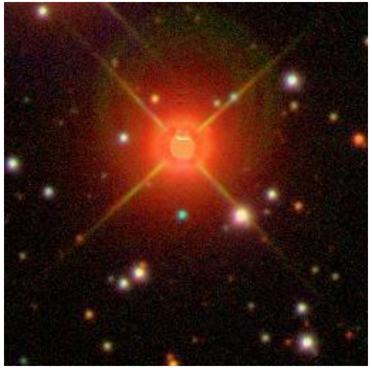
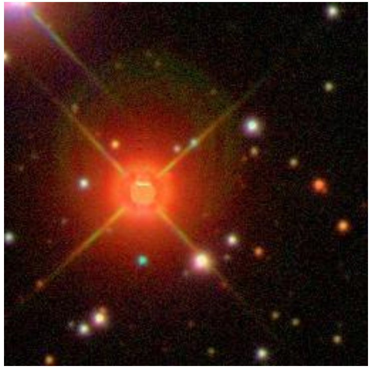
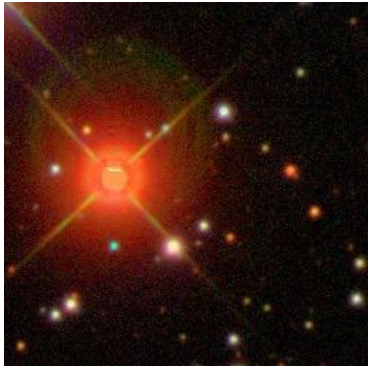


change in ra per height pixel:
0.00013222558226999104

Zoomed Pictures



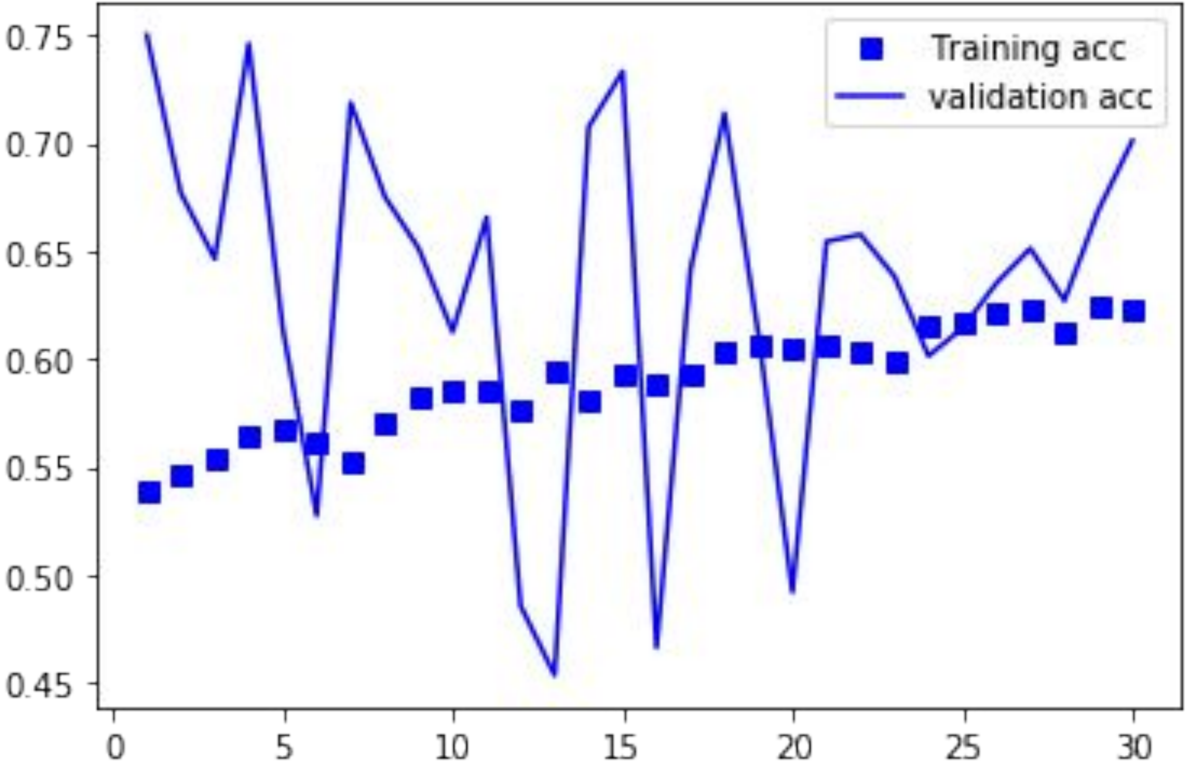
Note: In some fields, it is harder to pick out the target star simply they are further away; also, the algorithm for locating the stars within the field is not perfect

Neural Network: Trial 1

```
Layer (type)              Output Shape           Param #
=================================================================
conv2d_7 (Conv2D)         (None, 254, 254, 32)   896
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 127, 127, 32)  0
_________________________________________________________________
conv2d_8 (Conv2D)         (None, 125, 125, 64)   18496
_________________________________________________________________
max_pooling2d_8 (MaxPooling2 (None, 62, 62, 64)    0
_________________________________________________________________
conv2d_9 (Conv2D)         (None, 60, 60, 64)     36928
_________________________________________________________________
max_pooling2d_9 (MaxPooling2 (None, 30, 30, 64)    0
_________________________________________________________________
flatten_3 (Flatten)       (None, 57600)          0
_________________________________________________________________
dense_3 (Dense)           (None, 512)            29491712
_________________________________________________________________
dense_4 (Dense)           (None, 1)              513
=================================================================
Total params: 29,548,545
Trainable params: 29,548,545
Non-trainable params: 0
_________________________________________________________________
```

Success



Training acc
validation acc
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0
5
10
15
20
25
30

Neural Network Trial 2

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
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conv2d_19 (Conv2D)           (None, 254, 254, 32)      896
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dropout_3 (Dropout)          (None, 254, 254, 32)      0
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conv2d_20 (Conv2D)           (None, 252, 252, 32)      9248
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max_pooling2d_16 (MaxPooling (None, 126, 126, 32)      0
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conv2d_21 (Conv2D)           (None, 124, 124, 64)      18496
_________________________________________________________________
max_pooling2d_17 (MaxPooling (None, 62, 62, 64)        0
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conv2d_22 (Conv2D)           (None, 60, 60, 64)        36928
_________________________________________________________________
max_pooling2d_18 (MaxPooling (None, 30, 30, 64)        0
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conv2d_23 (Conv2D)           (None, 28, 28, 64)        36928
_________________________________________________________________
flatten_6 (Flatten)          (None, 50176)             0
_________________________________________________________________
dense_9 (Dense)              (None, 512)               25690624
_________________________________________________________________
dense_10 (Dense)             (None, 1)                 513
=================================================================
Total params: 25,793,633
Trainable params: 25,793,633
Non-trainable params: 0
_________________________________________________________________
```
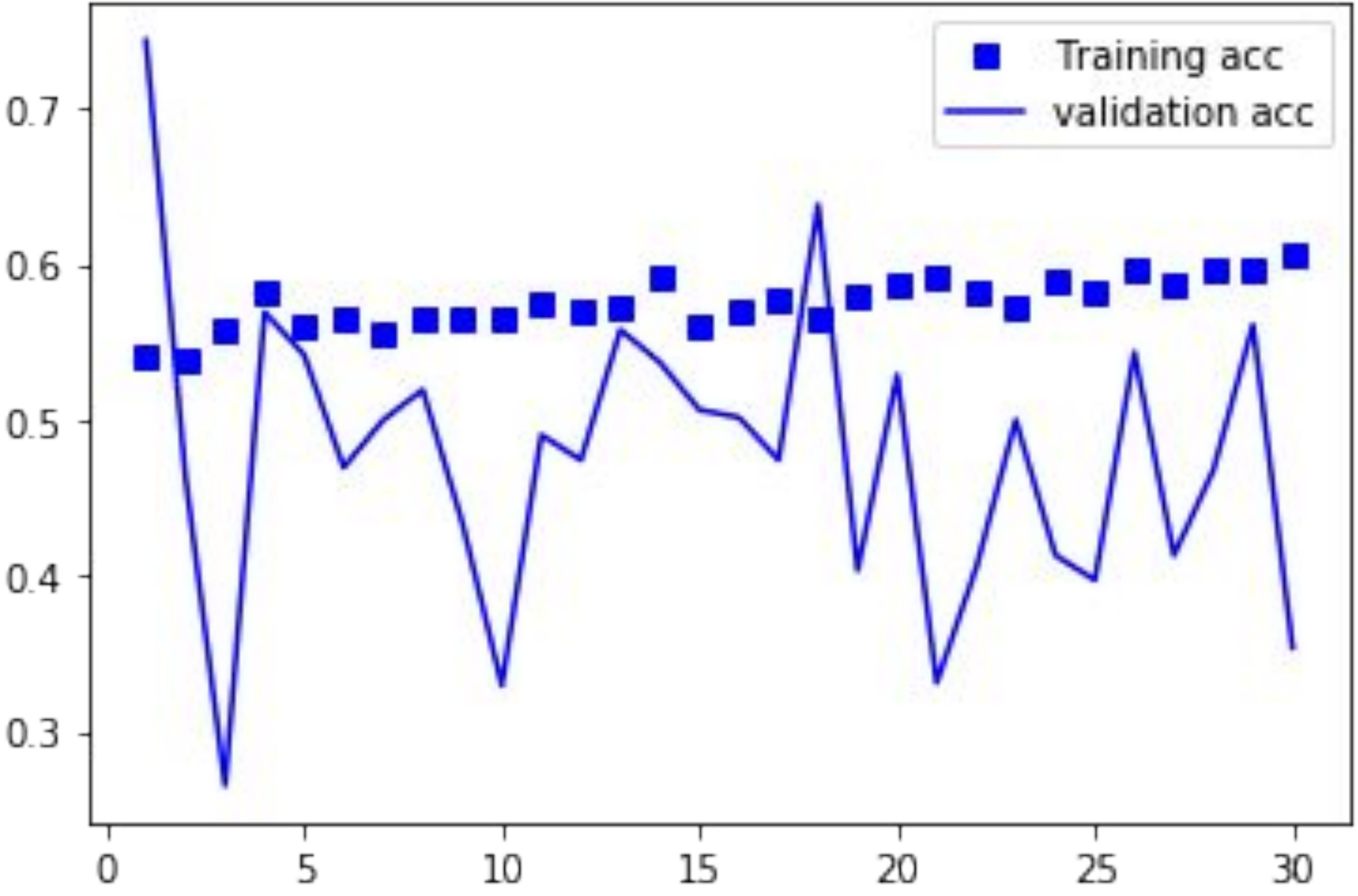

In [129]:

Accuracy



Why Search For Exoplanets?

SCI-TECH

1.3 million want to raid Area 51 to 'see them aliens'

"They can't stop us all."

But Seriously, Where Are the Aliens...

Life exists in the universe

Life Might Be A Natural Consequence of the Universe

The existence of life as we know it is really a property of the whole universe, not just an isolated feature of the planet earth

Drake Equation

Number of intelligent civilizations in our galaxy that we can communicate with

=

Average rate of star formation x
Average num of habitable planets per star x
Probability that a planet evolves life x
Probability that life evolves intelligence x
Probability that intelligence uses radio x
Average lifetime of a radioactive civilization

Conclusion

- Exoplanets, or extrasolar planets, are planets that exist outside our solar system
- There exists multiple clever ways to detect them, but they are all costly and time consuming or very narrow
- A computer model might be able to detect shared characteristics between solar systems containing exoplanets, and inform further search as well as make estimates about the number of exoplanets in the universe
- I created a neural network from pictures of solar systems with and without exoplanets which mostly failed to predict whether a system would have an exoplanet
- The search for and classification of exoplanets is a very important first step in the search for extraterrestrials