

# Fundamentals of Computing for Researchers (FCSR)

Final Student Project Showcase  
Bush Digital Telescope





# **FCSR - Fundamentals of Computing for Researchers - an experiential course**

Welcome!

We are Freshmen, Juniors, Seniors, and the very “senior” faculty

Anne, Armaan, Anya, Avie, Carter, Erik, Heidi, Luke, Madden, Philipp, Chandru

We learned about Jupyter Notebooks for digital research, Python Programming and use of Raspberry PI as a research tool

We studied basic Python Programming tasks and completed 2 projects

PLEASE HOLD YOUR QUESTIONS UNTIL THE END OF THIS PRESENTATION

# What are Jupyter Notebooks?

```
1 import random
2 playing = True
3
4 while playing:
5     question = input('ask the magic 8 ball a question')
6     answers = (random.randint(1, 9))
7     if question == "":
8         exit() # this is not correct
9     playing = False
10    elif answers == 1:
11        print('it is certain')
12    elif answers == 2:
13        print('I\'m not too sure about that')
14    elif answers == 3:
15        print('you will die tomorrow')
16    elif answers == 4:
17        print('oh no...')
18    elif answers == 5:
19        print('things are looking good')
20    elif answers == 6:
21        print('outlook not so good')
22    elif answers == 7:
23        print('sounds like a you problem')
24    elif answers == 8:
25        print('yeah for sure')
26    elif answers == 9:
27        print('baha never gonna happen')
```

## Madden's 8-Ball game

1. The 21st century digital and dynamic research notebook, computing environment, and publishing engine all rolled into one!
2. Browser-based from client laptop - no local software installation needed
3. Used by Berkeley Institute of Data Science - also used at Bush Math and CS depts
4. Almost anything related to Data Science and Python based research are published in Jupyter notebooks today
5. We used it every day in our class as our computing environment
6. We used it in our projects as a publishing tool
7. You will see examples throughout our presentation

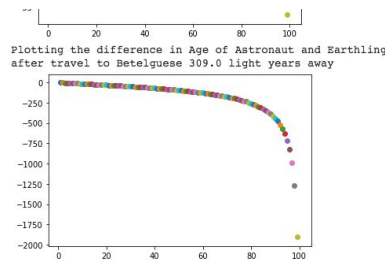
• Rock Paper Scissors Problem Set

2. Complete the Code Extract Below to complete the Rock Paper Scissors game

- Test the program thoroughly to see if the wins and counts are displayed correctly
- Make sure that the program completes without errors

```
1 import random
2 rpswin = True
3
4 while rpswin == True:
5     rpswin = input('press enter your choice of weapon')
6     rpswin = random.choice(['r','p','s'])
7     rpswin = random.choice(['r','p','s'])
8     rpswin = random.choice(['r','p','s'])
9     rpswin = random.choice(['r','p','s'])
10    rpswin = random.choice(['r','p','s'])
11    rpswin = random.choice(['r','p','s'])
12    rpswin = random.choice(['r','p','s'])
13    rpswin = random.choice(['r','p','s'])
14    rpswin = random.choice(['r','p','s'])
15    rpswin = random.choice(['r','p','s'])
16    rpswin = random.choice(['r','p','s'])
17    rpswin = random.choice(['r','p','s'])
18    rpswin = random.choice(['r','p','s'])
19    rpswin = random.choice(['r','p','s'])
20    rpswin = random.choice(['r','p','s'])
21    rpswin = random.choice(['r','p','s'])
22    rpswin = random.choice(['r','p','s'])
23    rpswin = random.choice(['r','p','s'])
24    rpswin = random.choice(['r','p','s'])
25    rpswin = random.choice(['r','p','s'])
26    rpswin = random.choice(['r','p','s'])
27    rpswin = random.choice(['r','p','s'])
28    rpswin = random.choice(['r','p','s'])
29    rpswin = random.choice(['r','p','s'])
30    rpswin = random.choice(['r','p','s'])
```

## Heidi's RPS

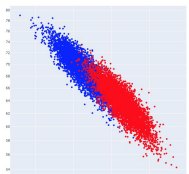


## Luke's Space Travel



# A synopsis of the first FCSR project - Lives of Stars - Scale of the Universe

Height vs Weight of Males and Females

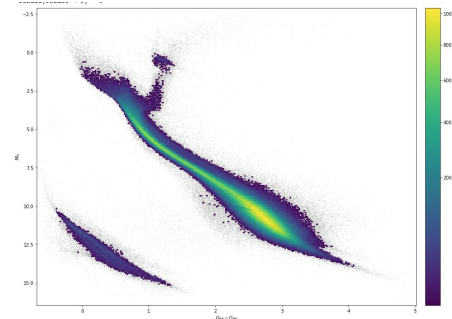


Convert Right Ascension (RA) and Declination (Dec) to J2000 Equatorial Coordinates (RA, Dec)

ra\_hours: 5  
 ra\_minute: 55  
 ra\_second: 10.305  
 dec\_degree: North  
 dec\_degree: 7  
 dec\_minute: 24  
 dec\_second: 25.43

5 55 10.305 North 1.0 7.24 25.43  
 RA in degrees: 88.7929  
 Dec in degrees: 7.4071

1. Studied the lifecycle of a star using the Hertzsprung Russell Diagram (HRD)
2. Learned to handle large datasets from robotic astronomical satellites
3. Clean and analyze datasets as individual and connected series (columns)
4. Created celestial coordinate converters with user interactivity
5. Static and dynamic (interactive) plotting of related dataset points
6. Studies locations of hot (blue) and cool (red) stars on the HRD
7. Published results in a dynamic Jupyter Notebook
8. [Anya's interactive Height-vs-Weight Jupyter notebook](#)
9. [Example of Erik's Right-Ascension Declination converter](#)
10. [Team Project plot of 1M stars with 200 parsecs of our Sun](#)

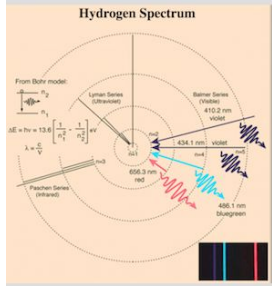




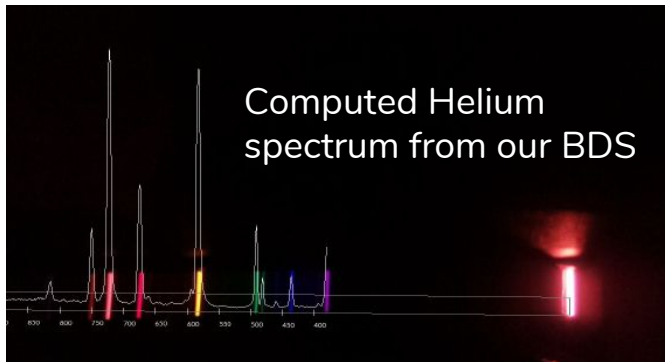
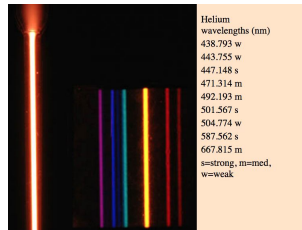
# Bush Digital Spectroscope Project Objectives

1. Apply computing technologies learned to a hands-on project
  - a. Jupyter Notebooks
  - b. Python programming language
  - c. Raspberry Pi “pocket” computer (RPI)
2. Build a scientific instrument (BDS) and automate it using RPI & Python code
3. Create, collect and analyze scientific data for research (emission wavelength spectra)
4. Present Live BDS results to Faculty and Peers using the created Jupyter Notebook
5. Contribute BDS and operating instructions to Bob Huffman and his Astronomy classroom

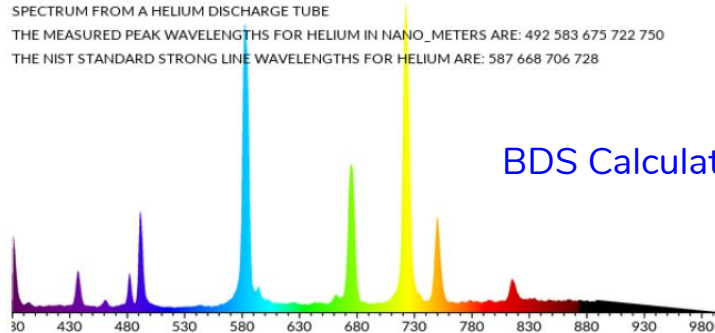
# What causes an emission spectrum?



1. Atoms of a gas are heated to high temperatures in the middle of stars or in a discharge tube
2. This causes the electrons to get excited (energized) and jump to an outer orbital
3. It then quickly falls back to its original inner orbital releasing photons of a specific frequency/wavelength or a specific color (VIBGYOR)
4. The bigger the jump the more energy released (higher freq, smaller wl). Some of these freq are in the visible range called the Balmer spectrum
5. Light from the sun (or discharge tubes) emit these light of specific freq (colored spectral lines) which can be seen when diffracted by a prism or diffraction grating



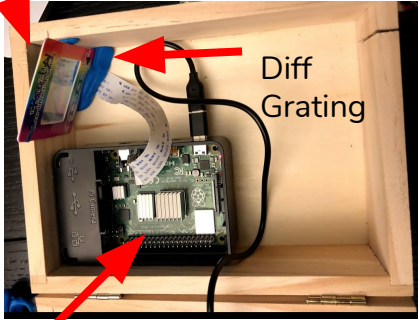
SPECTRUM FROM A HELIUM DISCHARGE TUBE  
 THE MEASURED PEAK WAVELENGTHS FOR HELIUM IN NANO\_METERS ARE: 492 583 675 722 750  
 THE NIST STANDARD STRONG LINE WAVELENGTHS FOR HELIUM ARE: 587 668 706 728



BDS Calculated Peaks!

# Building the Digital Spectroscope

Camera



Diff  
Grating

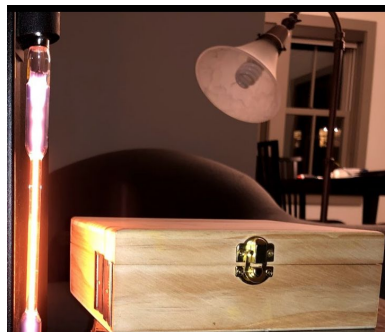
RPI



Five teams of 2 students each built a Spectroscope  
One is being passed around for you to look at  
It is actually functioning as you are looking at it!

When enclosed it  
provides a perfectly dark  
environment for spectral  
images

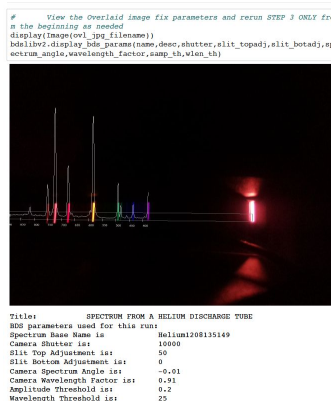
# Communicating with the RPI



Discharge Tube,  
Daylight, a  
Cuvette, or other  
sources of light  
emitted from the  
source being  
analyzed on BDS  
running Jupyter  
Server



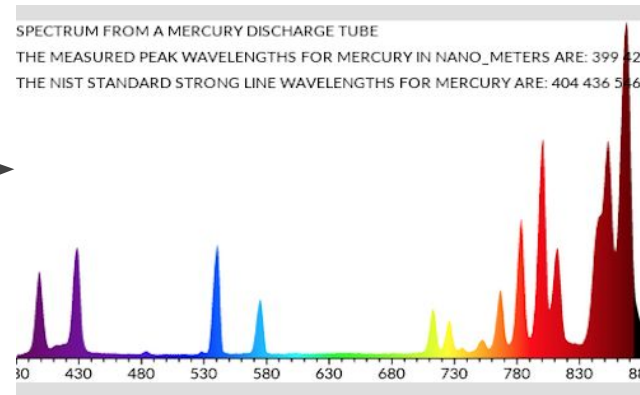
100% wireless!



BDS Jupyter  
Notebook  
accessed  
via remote  
laptop



Spectrum and  
Peak  
Wavelengths  
computed  
using Python  
code running  
on the BDS

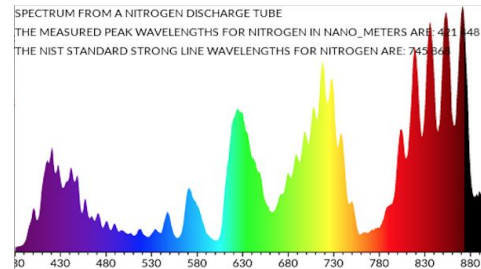
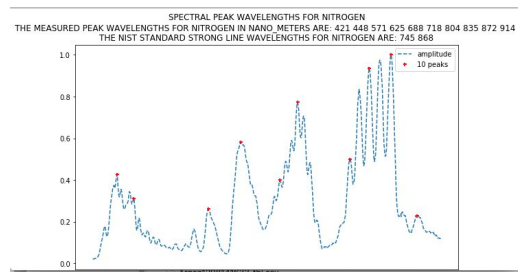
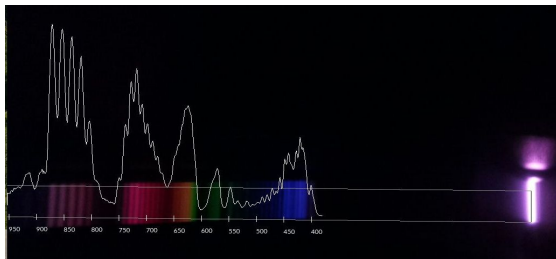


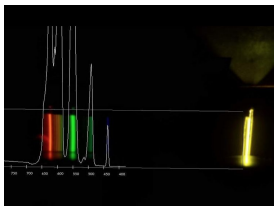
Results delivered remotely  
to the laptop Browser. This  
is the spectrum of Mercury



# Live Walkthrough of Python Code in the BDS via Jupyter Notebook

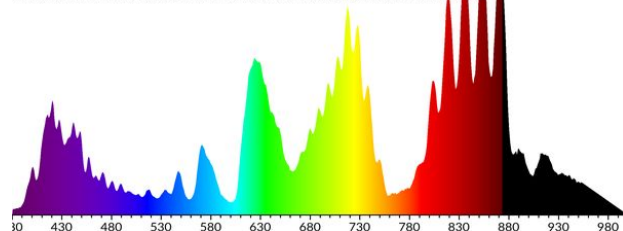
1. Obtain Raw Image of Spectrum
2. Create Pixel Array of Raw Image (R G B intensities for each pixel)
3. Locate the slit in the Pixel Image (brightest vertical line about 3/5ths down to the right
  - a. (this is where the Python is looking for the slit)
4. Draw an aperture to contain spectrum (a rectangular area of analysis)
5. Compute the Wavelength Peaks where the maximum brightness occurred (spectral lines) within the aperture box
6. Compare with the standard for the element under analysis





# Live Runs of BDS

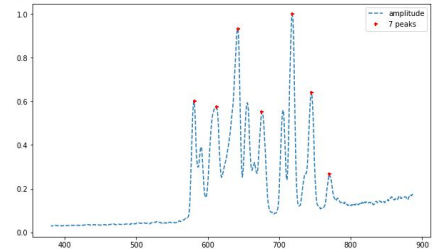
SPECTRUM FROM A NITROGEN DISCHARGE TUBE  
 THE MEASURED PEAK WAVELENGTHS FOR NITROGEN IN NANO\_METERS ARE: 421 448 571 625 688 718 8  
 THE NIST STANDARD STRONG LINE WAVELENGTHS FOR NITROGEN ARE: 745 86



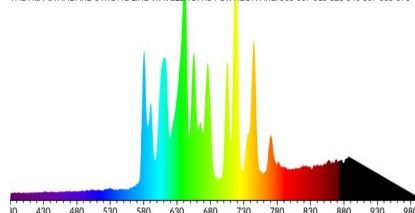
1. [Daylight Spectrum accessed via Avie/Armaan team BDS](#)
2. [Compact Fluorescent Lamp Spectrum obtained via Anya/Madden team BDS](#)
3. [Bright LED spectrum obtained via Erik/Philipp team BDS](#)
4. [Helium Discharge Tube Spectrum obtained via Luke/Heidi BDS](#)
5. [Mercury Discharge Tube Spectrum obtained via Anne/Carter BDS](#)

We will do this simultaneously as we are connected to all 5 BDS remotely via a single laptop!

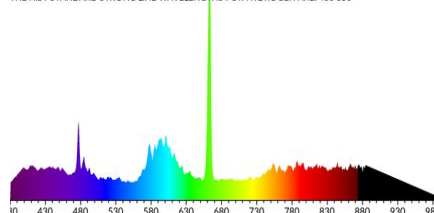
SPECTRAL PEAK WAVELENGTHS FOR NEON  
 THE MEASURED PEAK WAVELENGTHS FOR NEON IN NANO\_METERS ARE: 581 612 642 676 718 745 770  
 THE NIST STANDARD STRONG LINE WAVELENGTHS FOR NEON ARE: 585 607 615 626 640 837 865 878



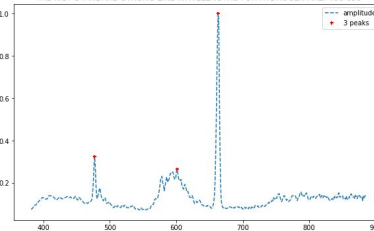
SPECTRUM FROM A NEON DISCHARGE TUBE  
 THE MEASURED PEAK WAVELENGTHS FOR NEON IN NANO\_METERS ARE: 581 612 642 676 718 745 770  
 THE NIST STANDARD STRONG LINE WAVELENGTHS FOR NEON ARE: 585 607 615 626 640 837 865 878



SPECTRUM FROM A HYDROGEN DISCHARGE TUBE  
 THE MEASURED PEAK WAVELENGTHS FOR HYDROGEN IN NANO\_METERS ARE: 477 601 663  
 THE NIST STANDARD STRONG LINE WAVELENGTHS FOR HYDROGEN ARE: 486 656



SPECTRAL PEAK WAVELENGTHS FOR HYDROGEN  
 THE MEASURED PEAK WAVELENGTHS FOR HYDROGEN IN NANO\_METERS ARE: 477 601 663  
 THE NIST STANDARD STRONG LINE WAVELENGTHS FOR HYDROGEN ARE: 486 656





# Results and Feedback

1. Thanks for listening
2. Contribution of BDS to Bob Huffman's Physics and other science classrooms
3. Do you believe that we met BDS and course objectives?
4. QUESTIONS ??

