Baseball: The Impact of Drag Coefficient

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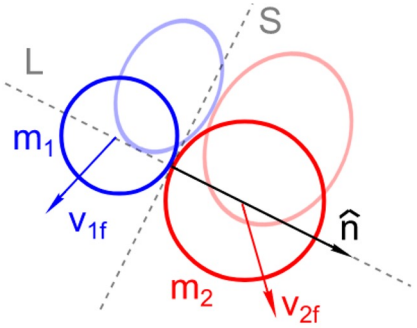
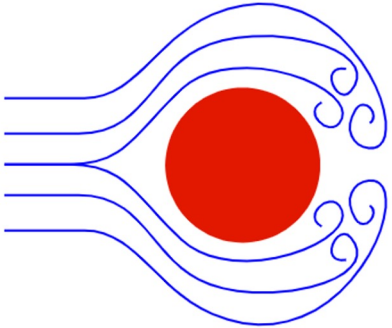
Introduction to Drag Coefficients of baseballs

What impacts the flight of a baseball?

“The performance of the baseball is primarily driven by two factors: the coefficient of restitution (“COR”), which impacts the exit velocity of the ball off the bat, and the drag coefficient, which impacts how far a batted ball carries once struck.” [1]



[2]



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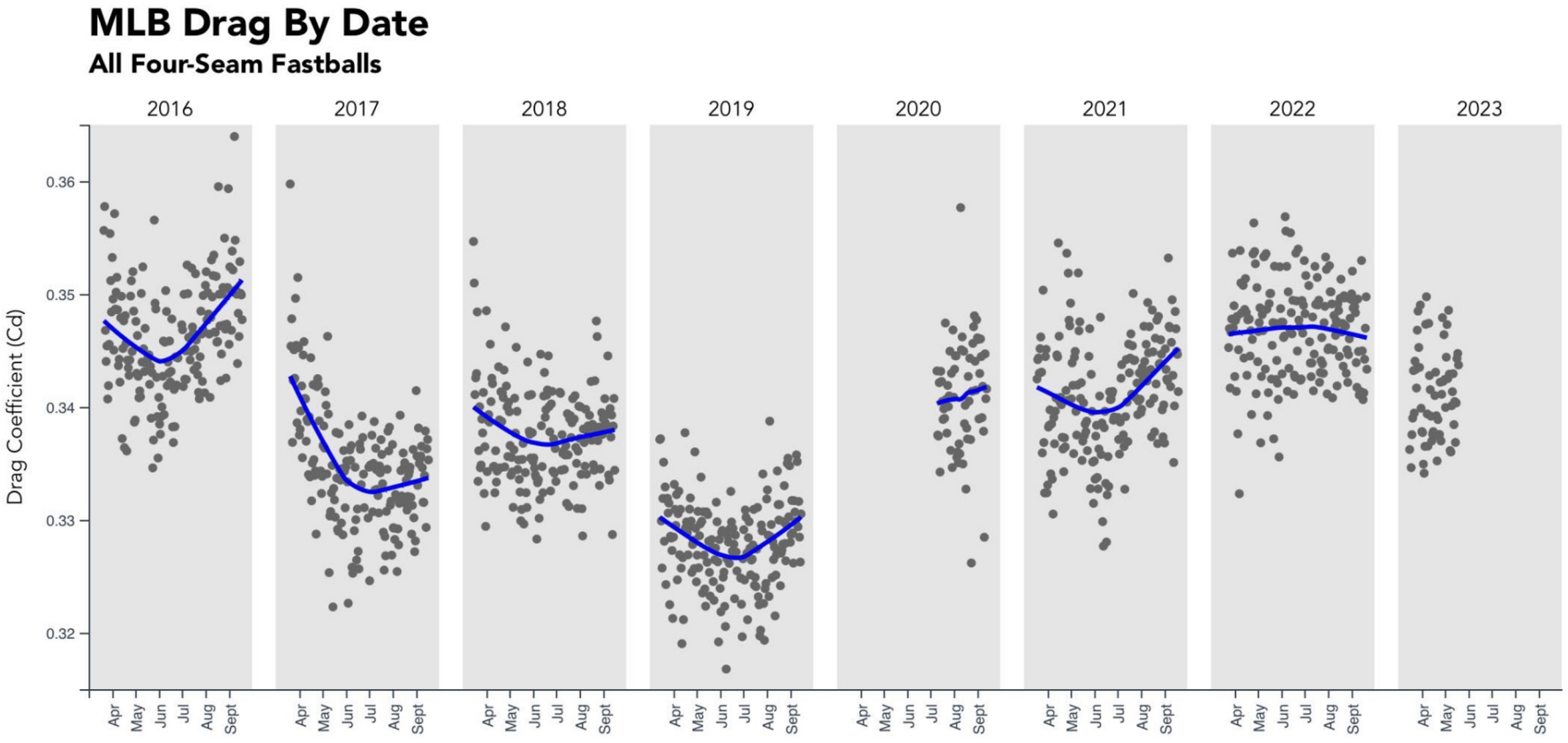

MLB Drag By Date
All Four-Seam Fastballs
2016
2017
2018
2019
2020
2021
2022
2023
Drag Coefficient (Cd)
0.36
0.35
0.34
0.33
0.32
Apr
May
Jun
Jul
Aug
Sept

[1]

Tools

Tools

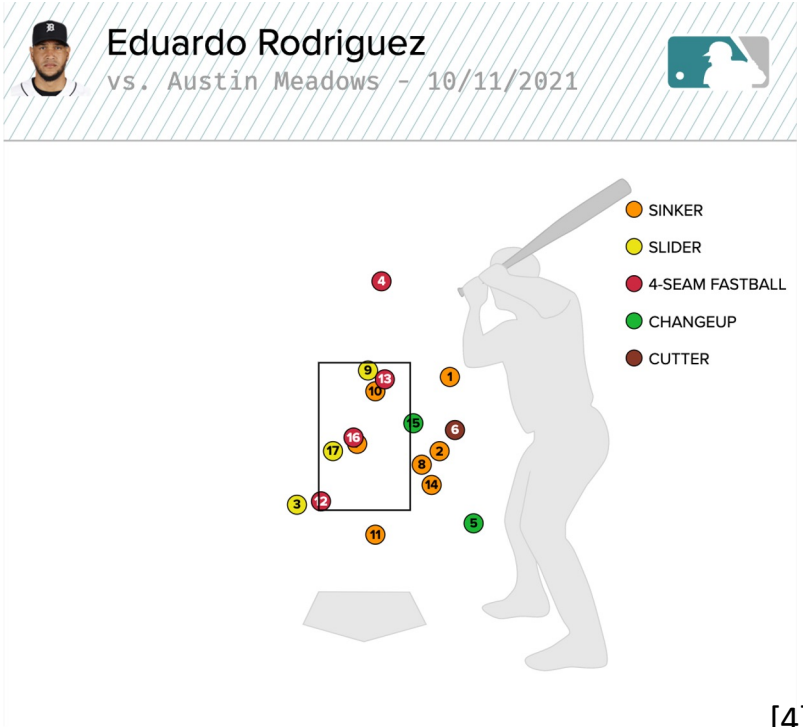
- Device: Apple MacBook Air, ThinkPad L14, ASUS TUF A15
- IDE: VS Code, Pycharm
- Python Packages:
  - pybaseball
  - pandas
  - xlwings
  - openpyxl
  - matplotlib
  - math

Data Type

Data Type

Plate_x, Plate_z:

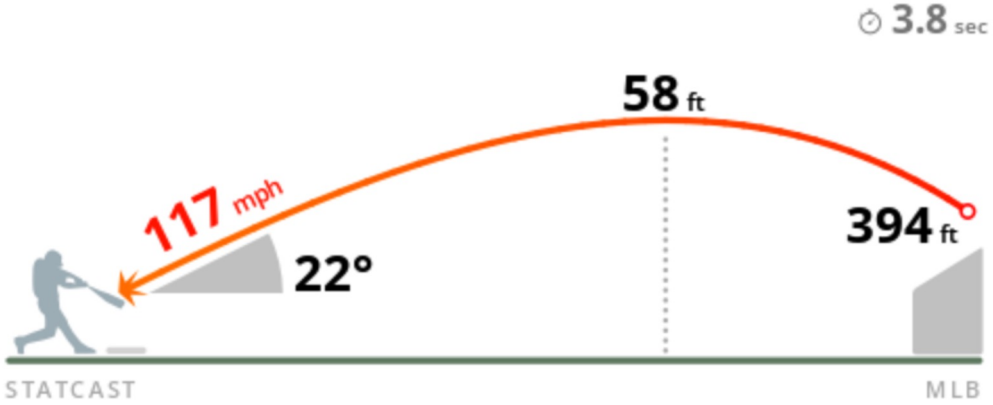
Location in the strikezone



[4]

Data Type

Hit distance, Exit velo, Launch Angle

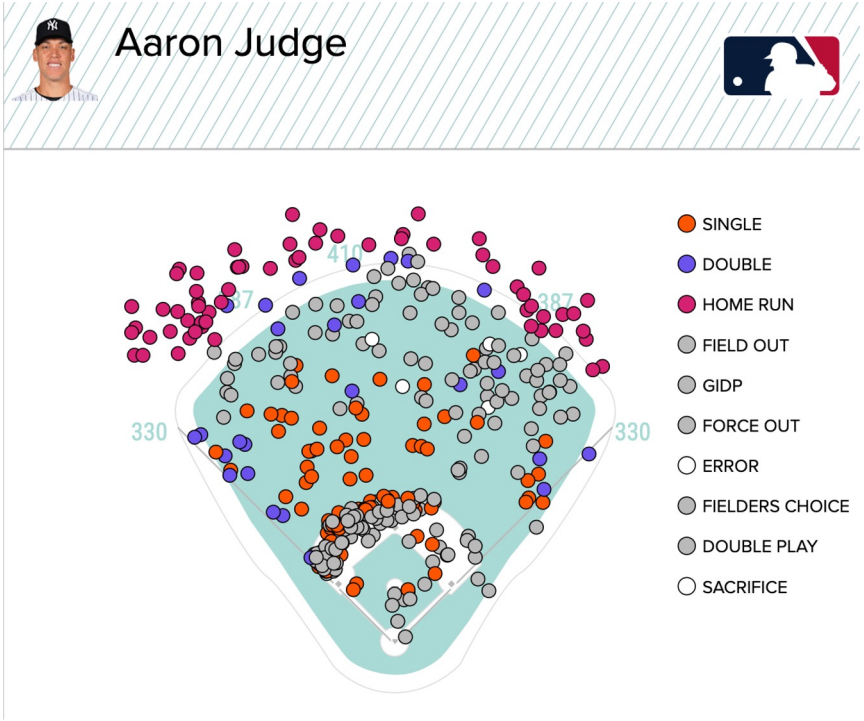


[4]

Data Type

hc_x, hc_y:

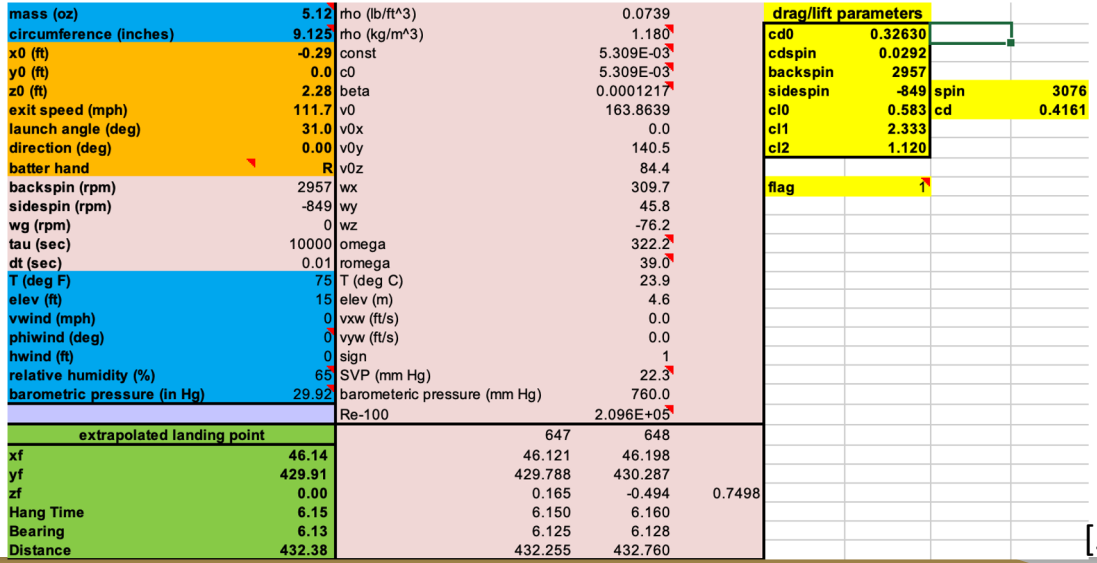
landing location of the ball on the field



[4]

Other Data Type (not obtained through API)

- Drag Coefficient (estimated)
- Spray Angle (calculated using hc_x and hc_y)
- Projected Distance (Trajectory Calculator by Professor Alan Nathan)



mass (oz)	5.12	rho (lb/ft^3)	0.0739		drag/lift parameters		
circumference (inches)	9.125	rho (kg/m^3)	1.180		cd0	0.32630	
x0 (ft)	-0.29	const	5.309E-03		cdspin	0.0292	
y0 (ft)	0.0	c0	5.309E-03		backspin	2957	
z0 (ft)	2.28	beta	0.0001217		sidespin	-849	spin 3076
exit speed (mph)	111.7	v0	163.8639		cl0	0.583	cd 0.4161
launch angle (deg)	31.0	v0x	0.0		cl1	2.333	
direction (deg)	0.00	v0y	140.5		cl2	1.120	
batter hand	R	v0z	84.4				
backspin (rpm)	2957	wx	309.7		flag	1	
sidespin (rpm)	-849	wy	45.8				
wg (rpm)	0	wz	-76.2				
tau (sec)	10000	omega	322.2				
dt (sec)	0.01	romega	39.0				
T (deg F)	75	T (deg C)	23.9				
elev (ft)	15	elev (m)	4.6				
vwind (mph)	0	vxw (ft/s)	0.0				
phiwind (deg)	0	vyw (ft/s)	0.0				
hwind (ft)	0	sign	1				
relative humidity (%)	65	SVP (mm Hg)	22.3				
barometric pressure (in Hg)	29.92	barometeric pressure (mm Hg)	760.0				
		Re-100	2.096E+05				
extrapolated landing point			647	648			
xf	46.14		46.121	46.198			
yf	429.91		429.788	430.287			
zf	0.00		0.165	-0.494	0.7498		
Hang Time	6.15		6.150	6.160			
Bearing	6.13		6.125	6.128			
Distance	432.38		432.255	432.760			

[5]

Code Explaination

main.py

```
from pybaseball import *
import math
from Projected_distance import projected_distance

def spray_angle(x, y):
    angle = math.atan((x-130)/(213-y)) # Using an equation I found online to calculate the spray angle
    return math.degrees(angle)

def projected_x_y(dis, phi):
    p_x = 125+(dis*math.sin(math.radians(phi)))/(315/(100*1.4141213562))
    p_y = 205-(dis*math.cos(math.radians(phi)))/(315/(100*1.4141213562))
    return p_x, p_y

Cd = {'2022':0.347, '2021':0.343, '2020':0.341, '2019':0.3285, '2018':0.338, '2017':0.334, '2016':0.3465} # Cd0 numbers for every year
```

```
year = '2019'
stat_year = '202
player = playeric
key = player.at[
stat_range = sta
stats = stat_ran
stats_df = stats
stats_df = stats_
stats_df = stats_
stats_df = stats_
batted_ball_spra
distance = []
count = 0
for i in range(le
    hit_distance_
    hc_x = stats_
    hc_y = stats_
    spray = spra
    distance.appe
    batted_ball_
    count += 1
stats_df['spray_
stats_df.to_csv(
```

	game_date	events	bb_type	plate_x	plate_z	hit_distance_	launch_speed	launch_angle	hc_x	hc_y	spray_angle
18	2022/10/4	home_run	fly_ball	-0.03	2.76	391	100.2	35	38.02	66.8	-32.175565
111	2022/9/28	home_run	fly_ball	0.23	2.79	394	117.4	22	52.2	64.43	-27.639202
181	2022/9/25	field_out	fly_ball	-0.5	2.87	338	98.8	44	90.36	67.13	-15.202926
197	2022/9/24	field_out	fly_ball	-0.58	2.81	348	108.1	43	131.74	58.54	0.64541266
216	2022/9/23	field_out	fly_ball	-0.37	3.19	337	110.1	44	73.28	73.21	-22.084927
237	2022/9/22	field_out	fly_ball	-0.07	3.58	403	113	35	135.05	36.19	1.63602198
251	2022/9/21	double	fly_ball	0.25	3.37	304	101.1	24	46.15	118.09	-41.459585
277	2022/9/20	home_run	fly_ball	-0.3	2.3	430	111.6	24	57.04	38.57	-22.698421
284	2022/9/18	home_run	fly_ball	0.45	2.72	414	111.6	35	209.13	53.1	26.3295097
287	2022/9/18	home_run	fly_ball	0.02	2.78	443	110.3	30	38.82	41.18	-27.953624
291	2022/9/18	double	line_drive	-0.19	2.54	354	111.8	19	74.13	65.5	-20.745669
372	2022/9/13	home_run	fly_ball	0.31	3.06	383	109.7	24	184.66	55.55	19.1448448
379	2022/9/13	home_run	fly_ball	0.14	2.71	389	100.5	35	35.71	69.57	-33.320673
457	2022/9/7	home_run	fly_ball	0.24	2.7	374	102.1	28	46.6	70.18	-30.28287
504	2022/9/5	home_run	fly_ball	0	2.86	404	109.6	34	15.28	77.03	-40.154846
520	2022/9/4	field_out	fly_ball	0.34	3.04	380	99.8	33	126.83	45.62	-1.0849917
537	2022/9/3	home_run	fly_ball	0.42	2.56	392	103.5	26	181.2	50.49	17.4874262
581	2022/8/30	home_run	fly_ball	0.26	3.81	378	107.5	36	182.7	57.29	18.6983733
605	2022/8/29	home_run	fly_ball	0.25	1.95	434	111.1	34	100.24	25.01	-8.995632
646	2022/8/26	home_run	fly_ball	0.02	2.56	427	109	31	127.95	26.19	-0.6287224
680	2022/8/23	home_run	fly_ball	-0.63	2.13	453	115.9	26	29.95	41.46	-30.252699
709	2022/8/22	home_run	fly_ball	0.32	2.13	383	109.6	26	207.24	66.48	27.7965629
791	2022/8/17	field_out	fly_ball	0.67	2.52	395	103.3	29	122.07	39.13	-2.6113814
811	2022/8/16	field_out	fly_ball	-0.36	2.31	284	98	45	150.05	87.69	9.09045525
888	2022/8/12	home_run	fly_ball	-0.55	3.76	429	113.8	31	58.45	38.32	-22.274307
922	2022/8/10	home_run	fly_ball	-0.14	2.28	412	105.2	32	39.57	55.59	-29.876808
961	2022/8/8	home_run	fly_ball	0.7	2.47	423	107.7	23	142.02	28.59	3.72931203
972	2022/8/7	double	fly_ball	0.19	2.54	403	111.7	22	130.9	35.95	0.29124969
997	2022/8/6	field_out	fly_ball	0.33	2.98	375	99	37	141.66	47.88	4.0392542
1053	2022/8/1	home_run	fly_ball	-0.56	3.18	420	105.5	29	83.3	34.35	-14.649593
1057	2022/8/1	double	fly_ball	0.32	2.22	382	110.8	22	68.73	55.15	-21.213887
1092	2022/7/30	home_run	line_drive	0.29	2.41	364	105.2	22	195.2	66.37	23.9726396
1125	2022/7/29	home_run	fly_ball	0.53	2.92	449	110.2	29	55.27	30.95	-22.317739
1129	2022/7/29	home_run	fly_ball	-0.34	3.13	370	105.1	29	195.28	66.24	23.9798737
1155	2022/7/28	home_run	fly_ball	-0.01	2.59	431	109.6	35	90.57	28.16	-12.041824
1177	2022/7/27	field_out	fly_ball	0.15	2.81	340	105.2	40	197	81.09	26.9270202

```
'hc_x','hc_y']]
```

```
trajectory_file = '../Drag_
visual_df = projected_dista
spray_copy = batted_ball_sp
batted_ball_spray_angle.ext
visual_df['spray_angle'] =

x, y = [], []
data = []
for j in range(len(visual_d
    projected = visual_df.i
    ang = visual_df.iat[j,
    projected_x, projected_
    x.append(projected_x)
    y.append(projected_y)
    if j < count:
        data.append(stat_ye
    else:
        data.append(year)
visual_df['hc_x'] = x
visual_df['hc_y'] = y
visual_df['events'] = data
visual_df.to_csv('../Drag_c
print (visual_df.to_string(
```

	distance	spray_angle	hc_x	hc_y	events
0	391	-32.175565	31.5272516	56.4273122	2022
1	394	-27.639202	42.9461717	48.3067188	2022
2	338	-15.202926	85.2086017	58.5728739	2022
3	348	0.64541266	126.759791	48.7831715	2022
4	337	-22.084927	68.1184577	64.8118689	2022
5	403	1.63602198	130.165218	24.1560006	2022
6	304	-41.459585	34.6417562	102.723305	2022
7	430	-22.698421	50.5100743	26.9123116	2022
8	414	26.3295097	207.433221	38.4250976	2022
9	443	-27.953624	31.776076	29.3284205	2022
10	354	-20.745669	68.7071953	56.3837714	2022
11	383	19.1448448	181.388733	42.5703253	2022
12	389	-33.320673	29.0699692	59.0752538	2022
13	374	-30.28287	40.3337343	60.011558	2022
14	404	-40.154846	8.04469315	66.3806392	2022
15	380	-1.0849917	121.76974	34.4381685	2022
16	392	17.4874262	177.881237	37.1537144	2022
17	378	18.6983733	179.401718	44.2620215	2022
18	434	-8.995632	94.5358402	12.561915	2022
19	427	-0.6287224	122.896553	13.3195349	2022
20	453	-30.252699	22.5421742	29.3316797	2022
21	383	27.7965629	205.181022	52.9010448	2022
22	395	-2.6113814	116.92076	27.8578177	2022
23	284	9.09045525	145.143452	79.1059384	2022
24	429	-22.274307	52.0005008	26.7812366	2022
25	412	-29.876808	32.865567	44.6231217	2022
26	423	3.72931203	137.351392	15.505814	2022
27	403	0.29124969	125.919649	24.0845893	2022
28	375	4.0392542	136.858401	37.0703912	2022
29	420	-14.649593	77.3145325	22.5801122	2022
30	382	-21.213887	62.9461529	45.1305733	2022

```
stance/TrajectoryCalculator.xlsx'

tance/Dataframe.csv')
```

Projected_distance.py

```python
from pybaseball import *
from openpyxl import load_workbook
import xlwings
import pandas as pd

def coefficient(cd, Y):
    drag = cd[Y]/1.0619
    return drag

def projected_distance(file, df, d, y, cd):
    new_df = pd.DataFrame()
```

Nathan, Alan M May 19, 2023, 12:43 AM

to me

In the most recent version of the TC (http://baseball.physics.illinois.edu/TrajectoryCalculator-new-3D-May2021.xlsx), and in the worksheet BattedBallTrajectory-2, default values are used for the drag coefficient and for spin rates. For a given spin rate, the actual drag coefficient is in cell I6. I would scale that value by the ratio of the Statcast Cd average values for the two years, approximately 1.06. You can get some idea about how that difference in Cd affects fly ball distances.

…Alan

```python
        wb.close()
        wb2 = xlwings.Book(file)
        sheet = wb2.sheets[0]
        distance = sheet['B29'].value
        projected_distance.append(distance)
        wb2.save()
        wb2.close()
    d.extend(projected_distance)
    new_df['distance'] = d
    return new_df
```

plot.py

```python
from pybaseball import *
import matplotlib.pyplot as plt

years = ['2022','2021','2020','2019','2018','2017','2016']
avg = [389.17,404.52,405.51,411.78,406.99,408.99,402.82]

def labels(a,b,c,n):
    if n==1:
        for i in range(len(a)):
            plt.text(i, b[i], b[i], ha='center', va='bottom', fontsize=8, weight='bold')
    else:
        for i in range(len(a)):
            plt.text(i, c[i]+20, b[i], ha='center', va='bottom', fontsize=8, weight='bold')

def avg_distance():
    plt.figure(figsize=(12, 5))
    colors = ['blue','grey','grey','red','grey','grey','grey']
    plt.bar(years, avg, color=colors, width=0.4)
    labels(years, avg, [], 1)

    plt.title("Difference in flight distance with different years' balls", fontsize='12')
    plt.xlabel('Year', fontsize='12')
    plt.ylabel('Distance', fontsize='12', rotation=360, horizontalalignment='right', verticalalignment='top')
    plt.show()
```

plot.py

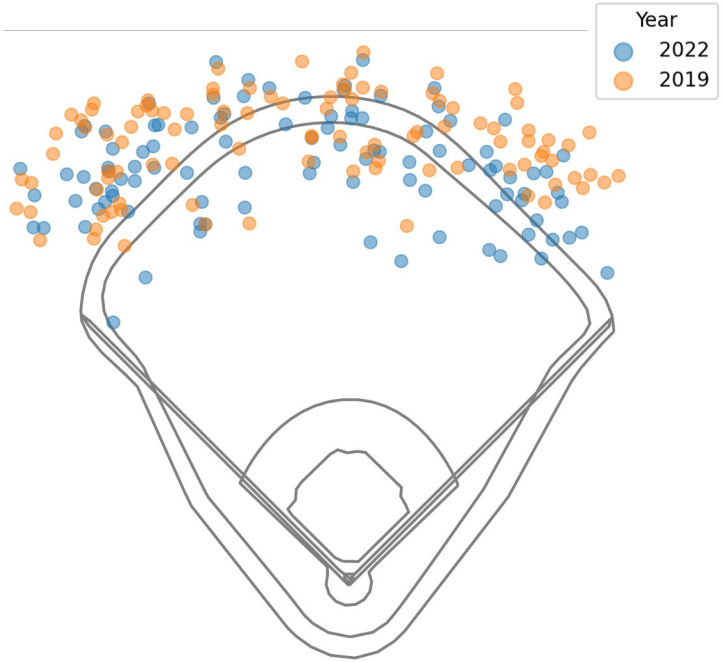
```
Cd0 = [0.347, 0.343, 0.341, 0.3285, 0.338, 0.334, 0.3465]

def homers():
    HR = []
    for year in years:
        data = team_batting(year)
        hr = 0
        for i in range(len(data)):
            hr += data.iat[i, 11]
        if year=='2020':
            hr = int(round(162/60*hr, 0)) # 2020 was a shortened season, so we scaled the numbers to a full 162 game season
        HR.append(hr)
    plt.figure(figsize=(10, 5))
    plt.plot(years, HR)
    labels(years, Cd0, HR, 2)

    plt.title("Difference in total homers with different years' balls", fontsize='12')
    plt.xlabel('Year', fontsize='12')
    plt.ylabel('Total', fontsize='12', rotation=360, horizontalalignment='right', verticalalignment='top')
    plt.show()
```

spraychart.py

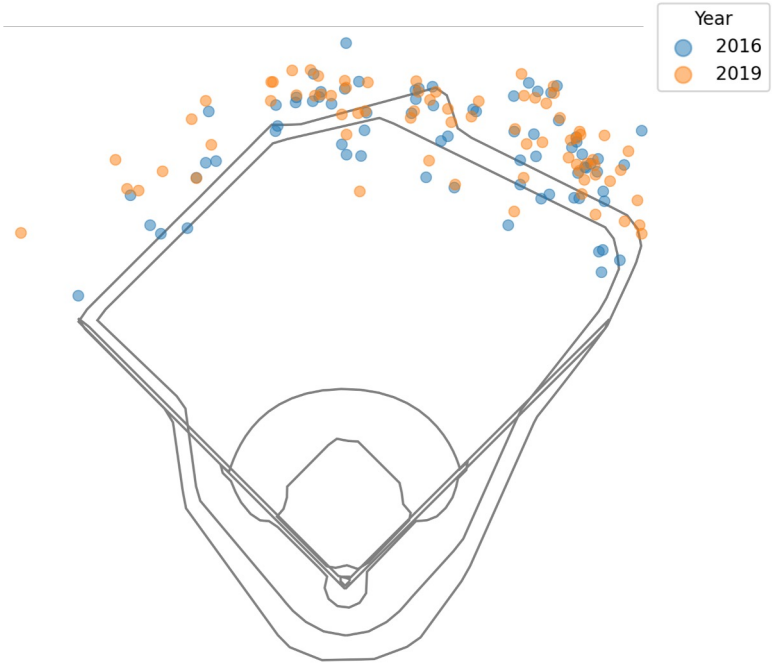
```
from pybaseball import *
import pandas as pd

stat_year = '2022'
df = pd.read_csv('../Drag_coefficients_in_baseball_and_the_impact_it_has_on_flight_distance/Dataframe.csv', nrows=204)
df['events'] = df['events'].astype(str)

spraychart(df, 'generic', title=f'{stat_year} Aaron Judge', size=80, colorby='events', legend_title='Year', width=3200, height=2000)
```

Data Analysis and visualization

Plot 1: Fly Ball Outcome with different Dc

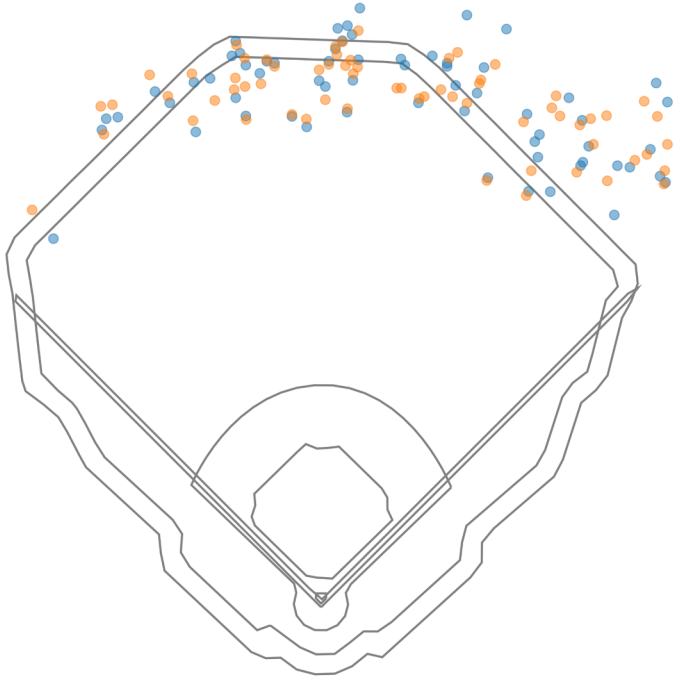


2022 Aaron Judge

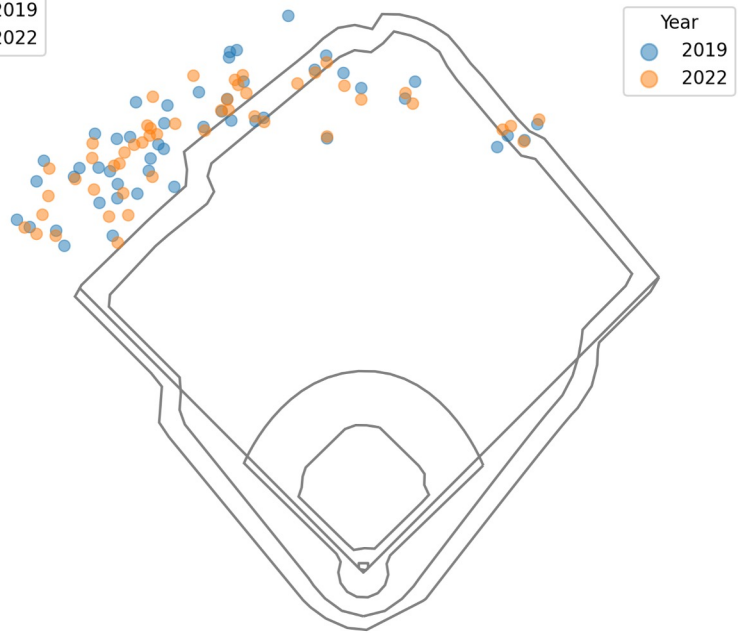


2016 David Ortiz

Plot 1: Fly Ball Outcome with different Dc

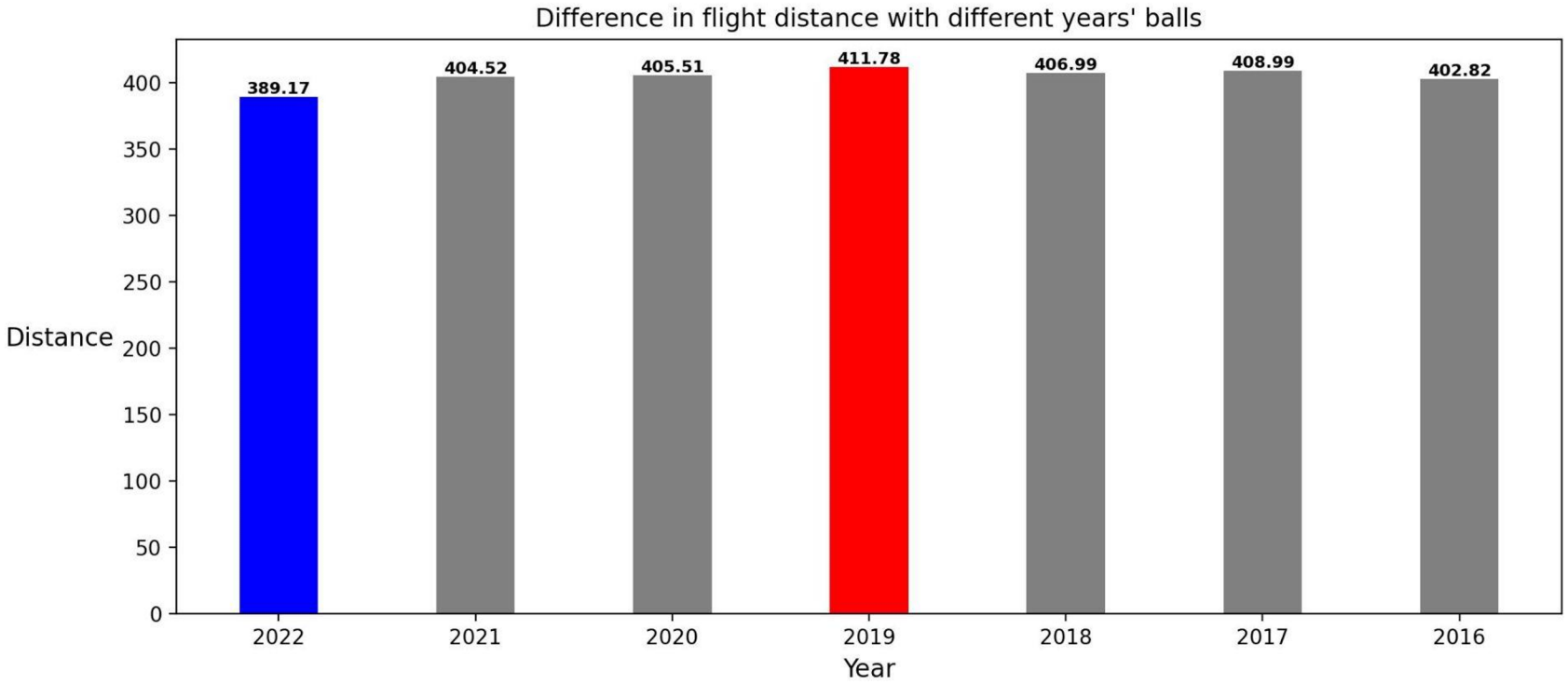


2019 Austin Meadows

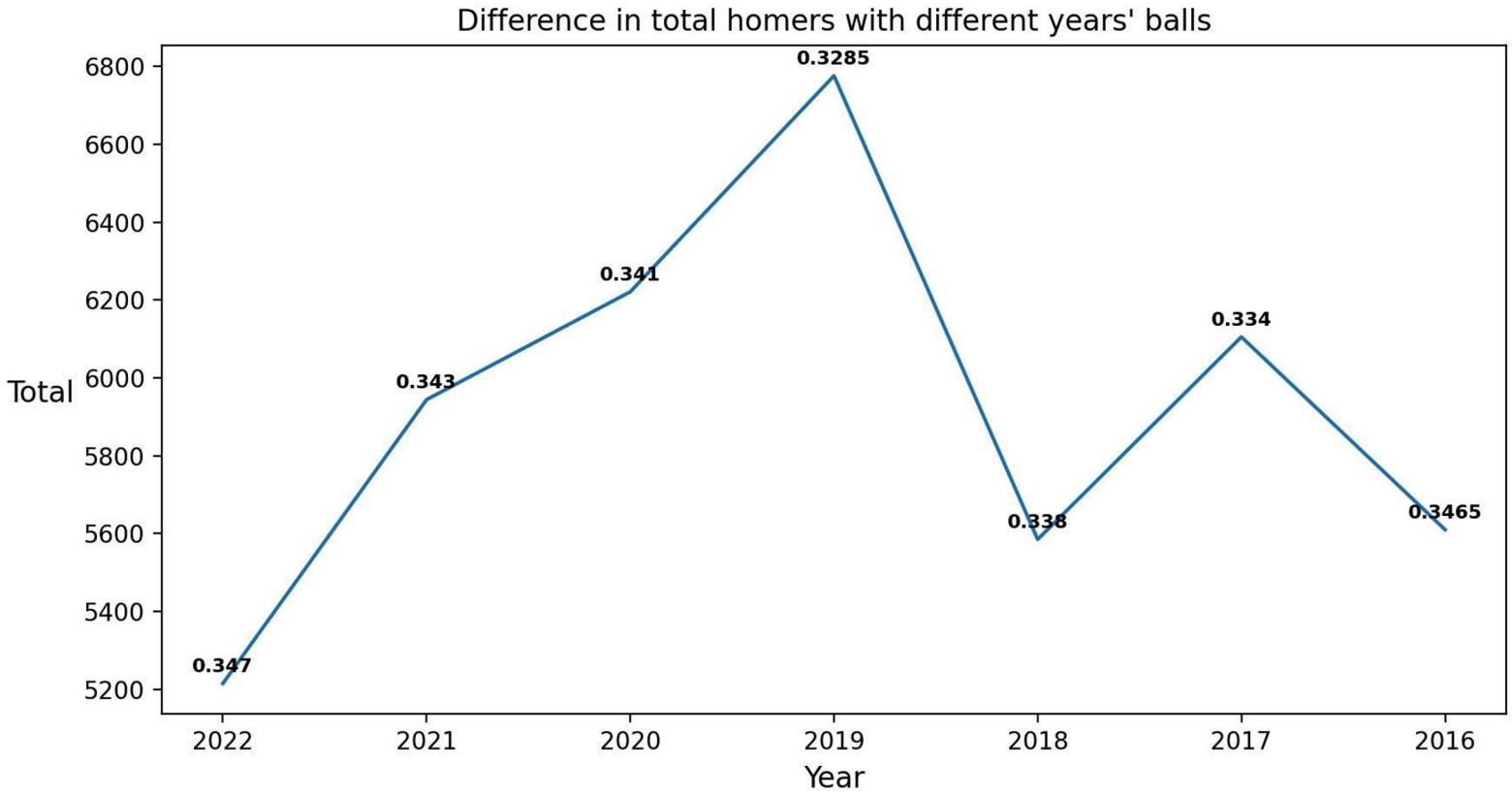


2019 Alex Bregman

Plot 2: Flight Distance Difference Through Out The Year



Plot 3: Total Homers With Different Years Ball



“Swing and a Miss”

- We try to tadium list
- Turns out nely difficult

15629	taipei	217.8615	115.1385	outfield_outer
15630	taipei	217.6938	114.6872	outfield_outer
15631	taipei	217.5242	114.2376	outfield_outer
15632	taipei	217.3529	113.7899	outfield_outer
15633	taipei	217.1798	113.3439	outfield_outer
15634	taipei	217.0049	112.8998	outfield_outer
15635	taipei	216.8283	112.4574	outfield_outer
15636	taipei	216.6498	112.0167	outfield_outer
15637	taipei	216.4697	111.5778	outfield_outer
15638	taipei	216.2877	111.1407	outfield_outer
15639	taipei	216.1041	110.7052	outfield_outer
15640	taipei	215.9188	110.2715	outfield_outer
15641	taipei	215.7317	109.8395	outfield_outer
15642	taipei	215.5429	109.4092	outfield_outer
15643	taipei	215.3525	108.9806	outfield_outer
15644	taipei	215.1604	108.5536	outfield_outer
15645	taipei	214.9666	108.1284	outfield_outer
15646	taipei	214.7711	107.7048	outfield_outer
15647	taipei	214.574	107.2828	outfield_outer

Conclusion

Conclusion

In our own research,when drag coeffiecient increases by 0.01, the flight distance decreases by around 4.978 ft. (The official is 5 ft.)

lower Drag Coefficient →→ longer flight distance →→ more homers

References

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Retrieved May 20, 2023

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3. “Drag (physics)”, Wikipedia, https://en.wikipedia.org/wiki/Drag_(physics), Retrieved June 4, 2023

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