

# FACTOR ANALYSIS OF PITCH DESIGN METRICS:

TILT, RELEASE HEIGHT, INDUCED VERTICAL BREAK,  
& HORIZONTAL BREAK

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# STUDY SIGNIFICANCE

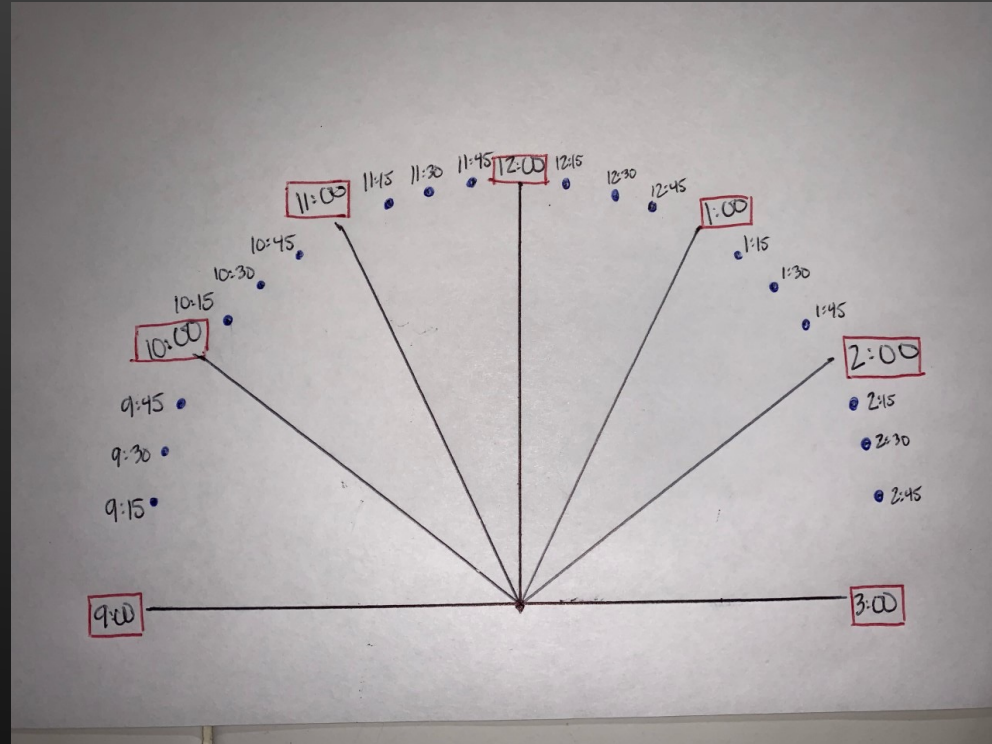
- Lower exit velocity means greater success (less runs on the board) as a pitcher.
- The fewer runs the opposing team scores, the easier it is to win the game.
- Wins matter.



# WHAT ARE THE FACTORS?

- Tilt
- Release Height
- Induced Vertical Break
- Horizontal Break

TRACKMAN  
BASEBALL

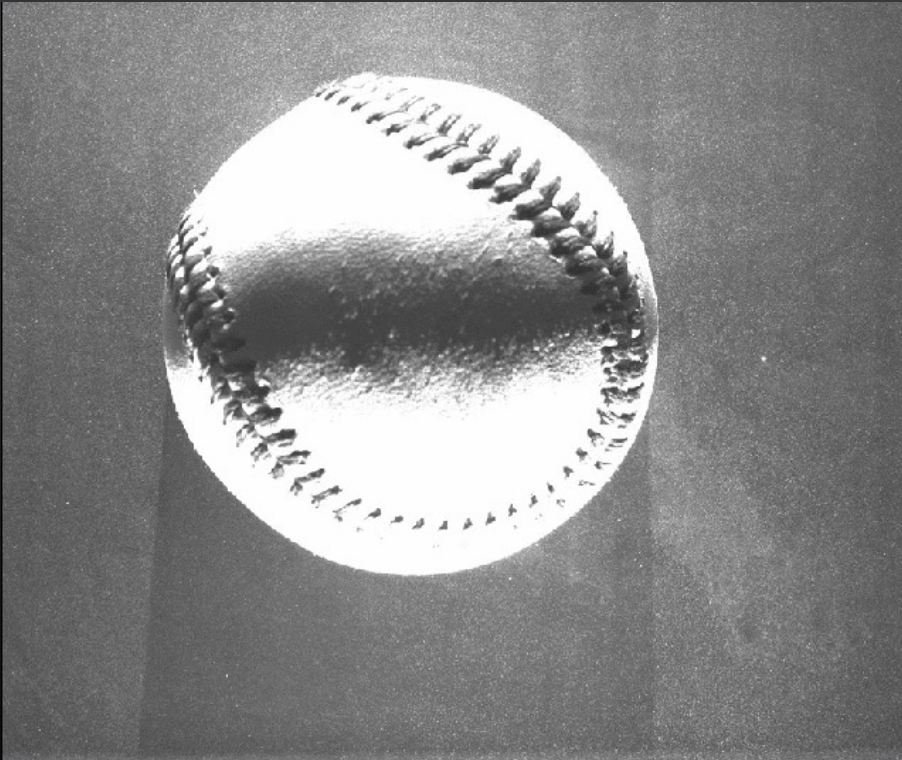


# MAGNUS FORCE/ EFFECT



<https://giphy.com/gifs/looks-towards-fastball-7PFsslFdPil0g>

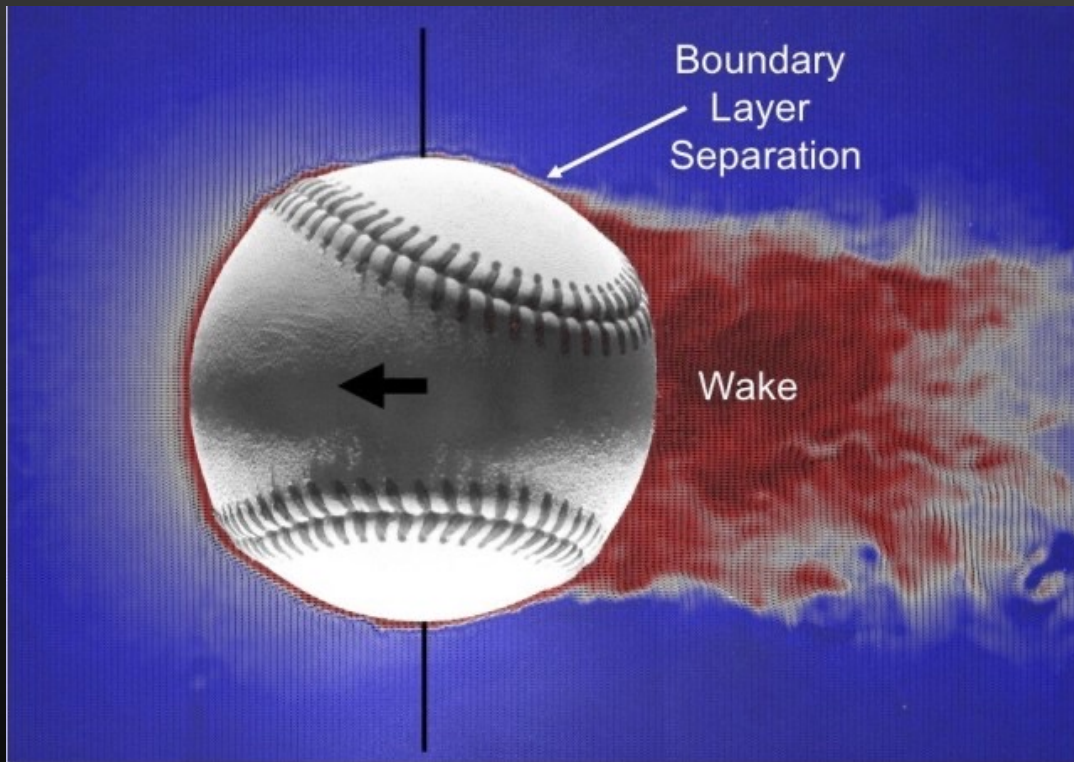
# PARTICLE IMAGE VELOCIMETRY (PIV)



Barton L. Smith

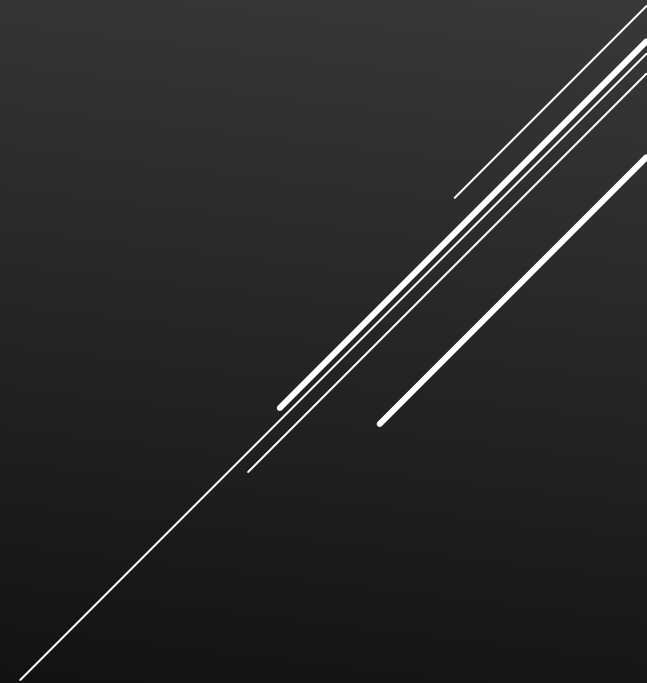


# BOUNDARY LAYER SEPARATION & WAKE



- Size
- Location
- Angle

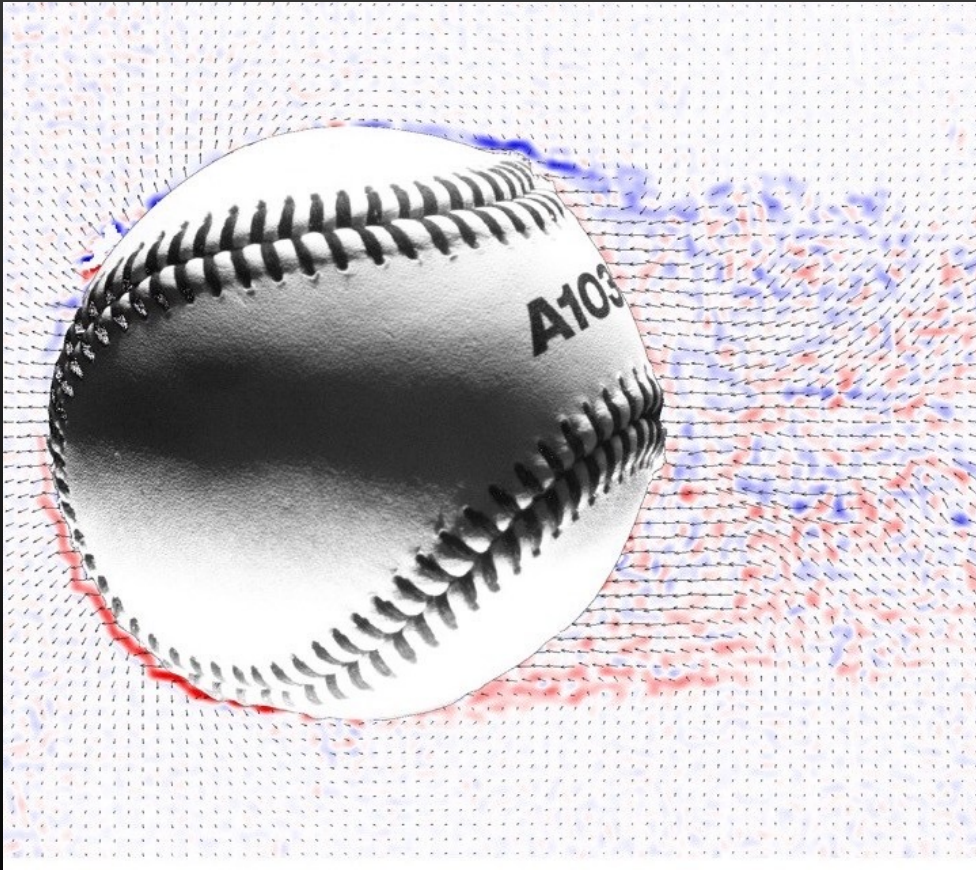
Barton L. Smith





# VORTICITY

$$-\omega = \nabla \times \mathbf{v}$$



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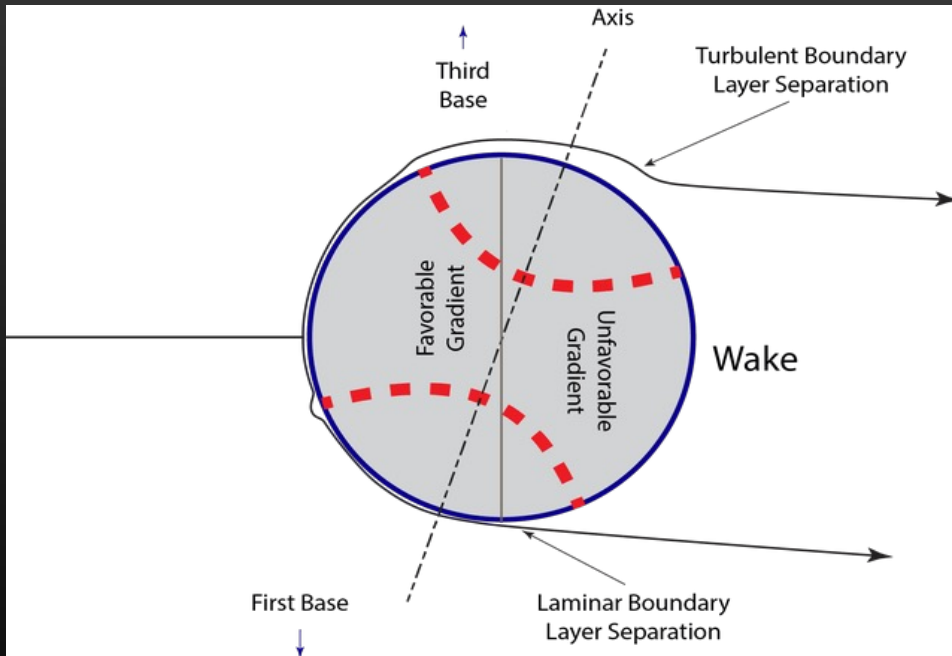
# THE LAMINAR EXPRESS



<http://i.imgur.com/vb9GLRC.gif>



# LAMINAR VS. TURBULENT FLOW

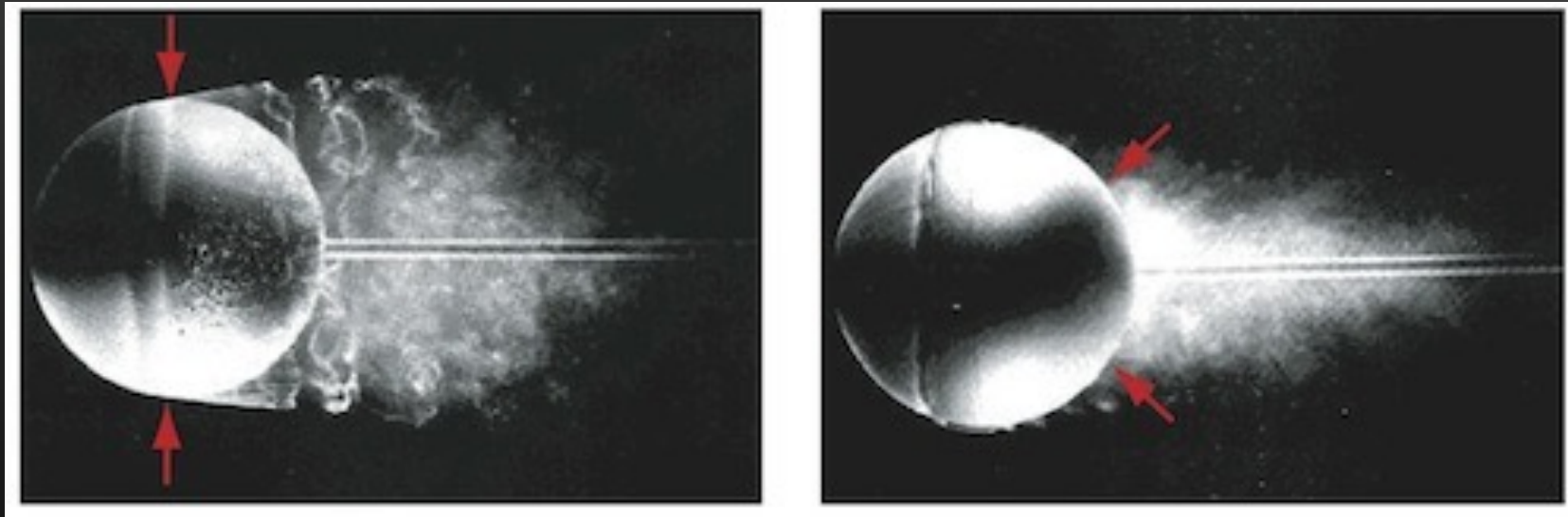


Barton L. Smith



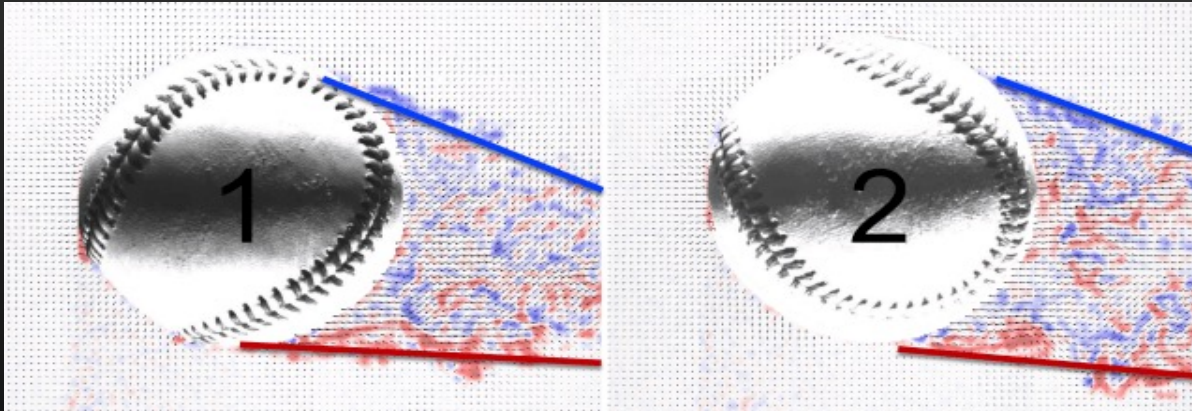
<https://giphy.com/gifs/comments-changeup-strasburg-115RAHRXu4zJzG>

# SEAMS

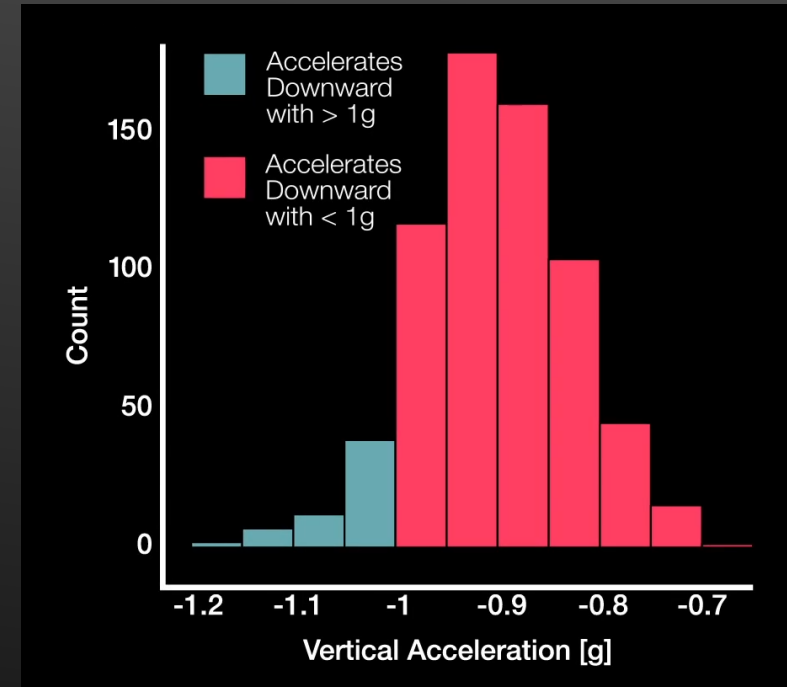


<https://plus.maths.org/content/fly-walks-round-football>

# TILT

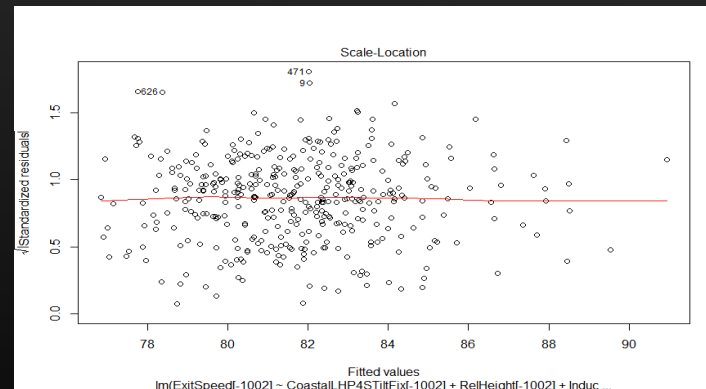
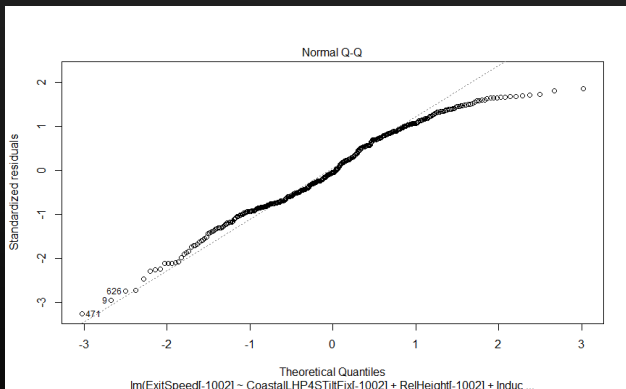
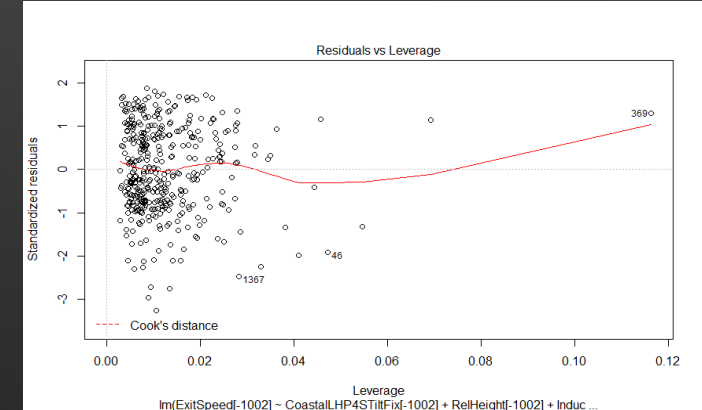
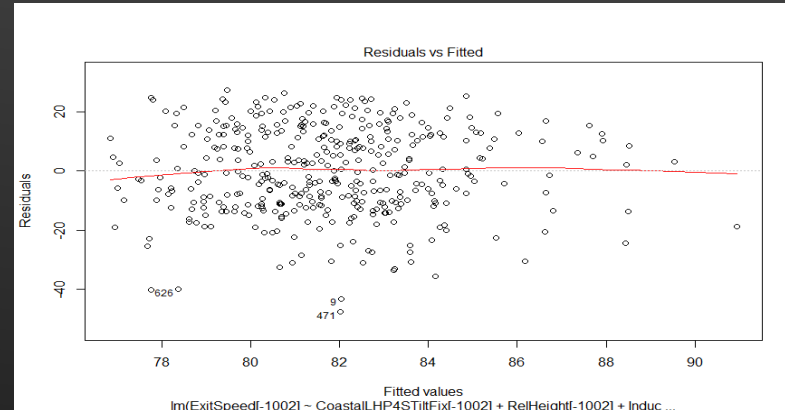
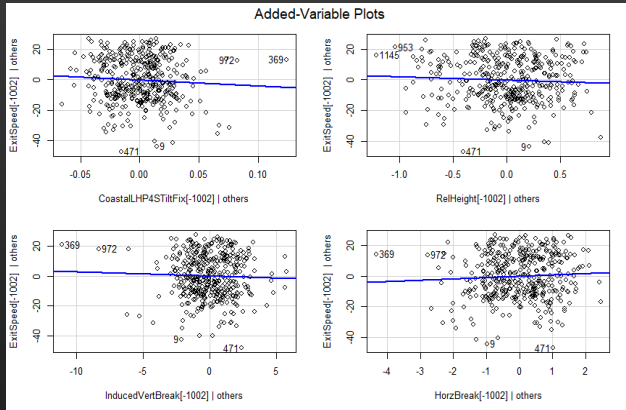


Barton L. Smith



-Stephen Strasburg's changeup accelerates downward with  $> 1g$  about 10% of the time

# ASSUMPTIONS (MODEL VALIDITY)



# MODEL ANALYSIS

```
Call:
lm(formula = ExitSpeed[-1002] ~ CoastalLHP4STiltFix[-1002] +
  RelHeight[-1002] + InducedVertBreak[-1002] + HorzBreak[-1002])

Residuals:
    Min       1Q   Median       3Q      Max
-47.756 -10.746  -0.712   12.331   27.299

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)    222.6222    89.5427   2.486  0.0133 *
CoastalLHP4STiltFix[-1002] -39.6368    30.3245  -1.307  0.1919
RelHeight[-1002]    -2.1791     2.0209  -1.078  0.2816
InducedVertBreak[-1002]  -0.2771     0.3957  -0.700  0.4841
HorzBreak[-1002]     0.8386     0.7557   1.110  0.2678

---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 14.72 on 394 degrees of freedom
(1088 observations deleted due to missingness)
```



# MODEL ANALYSIS

## RHP4S- 2954 observations

```
> cor(cbind(CoastalRHP4STiltFix[-vector],RelHeight[-vector],InducedVertBreak[-vector],HorzBreak[-vector]), use="complete_obs")
```

	Tilt	RH	IDVB	HB
Tilt	1.00000000	0.04310193	0.3601804	-0.7851545
RH	0.04310193	1.00000000	-0.4767546	0.2207076
IDVB	0.36018039	-0.47675456	1.00000000	0.5796939
HB	-0.78515454	0.22070755	0.5796939	1.00000000

## RHP2S- 463 observations

```
> cor(cbind(CoastalRHP2STiltFix,RelHeight,InducedVertBreak,HorzBreak), use="complete_obs")
```

	Tilt	RH	IDVB	HB
Tilt	1.00000000	0.061117357	0.608046752	-0.3898831
RH	0.06111736	1.000000000	-0.006555828	0.1532094
IDVB	0.60804675	-0.006555828	1.000000000	0.5643322
HB	-0.38988306	0.153209450	0.564332233	1.00000000

## LHP4S- 1488 observations

```
> cor(cbind(CoastalLHP4STiltFix[-1002],RelHeight[-1002],InducedVertBreak[-1002],HorzBreak[-1002]), use="complete_obs")
```

	Tilt	RH	IDVB	HB
Tilt	1.00000000	0.16234788	0.1356247	-0.63892628
RH	0.1623479	1.000000000	-0.2279446	0.07092843
IDVB	0.1356247	-0.22794459	1.00000000	0.31965229
HB	-0.6389263	0.07092843	0.3196523	1.00000000


## LHP2S- 1651 observations

```
> cor(cbind(CoastalLHP2STiltFix,RelHeight,InducedVertBreak,HorzBreak), use="complete_obs")
```

	Tilt	RH	IDVB	HB
Tilt	1.00000000	0.1592002	0.5923583	-0.2309413
RH	0.1592002	1.00000000	-0.3816687	-0.2432283
IDVB	0.5923583	-0.3816687	1.00000000	0.3185459
HB	-0.2309413	-0.2432283	0.3185459	1.00000000

- Tilt/HB
- Tilt/IDVB
- RH/IDVB
- IDVB/HB

# FUTURE WORK

- Include a wider range of factors.
  - Include swing and miss into analysis.
  - Perform similar analysis to Changeups and Breaking Balls (Slider/Curveball).
  - Case-by-case analysis.
- 
- A series of white lines of varying lengths and orientations are positioned on the right side of the slide, creating a dynamic, abstract graphic element.

# CONCLUSION

- Nothing of any statistical significance between exit velocity and any of the factors.
- Analysis found relationships between Tilt and Induced Vertical Break, Release Height and Induced Vertical Break, Induced Vertical Break and Horizontal Break, and confirmed the relationship between Tilt and Horizontal Break



# ACKNOWLEDGEMENTS

-Dr. Lindsay Bell of Coastal Carolina University

-Barton Smith of Utah State University:  
<https://www.baseballaero.com/>

-Coastal Carolina University Baseball (Drew Thomas)

Several white lines of varying lengths and orientations are positioned in the bottom right corner of the slide, creating a modern, abstract graphic element.

# RELEASE HEIGHT

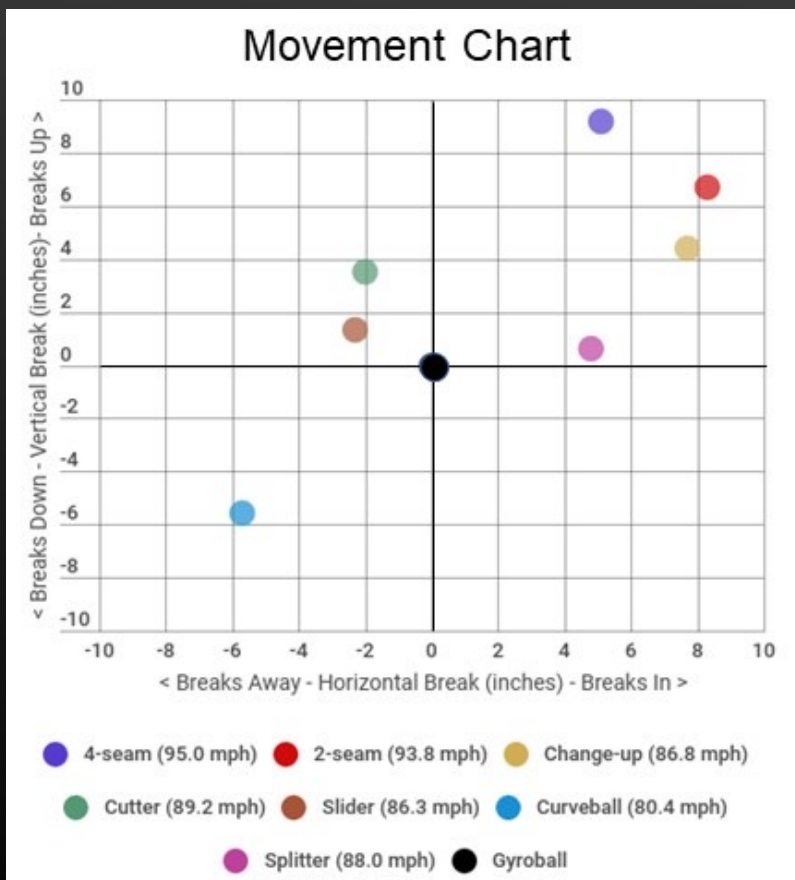


- The height above home plate at which the pitcher releases the ball, measured in feet.

<https://lehmanbaseball.wordpress.com/2016/01/14/custom-vs-one-size-fits-all-throwing-mechanics/>



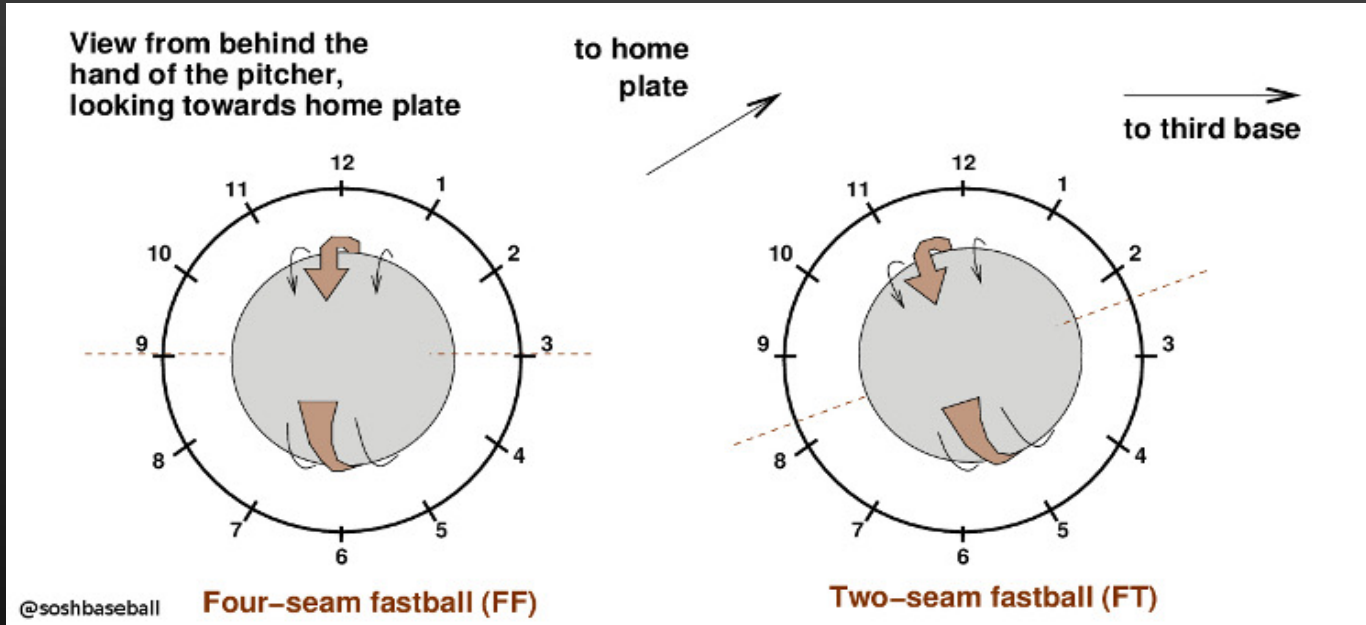
# HORIZONTAL & INDUCED VERTICAL BREAK



-The distance between where the pitch crosses the front of home plate versus where the pitch would have crossed home plate if it had traveled in a perfectly straight line from release, measured in inches.

-The distance between where the pitch crosses the plate and where it would have crossed the plate if it would have traveled in a perfectly straight line from release, unaffected by gravity, measured in inches.

# TILT

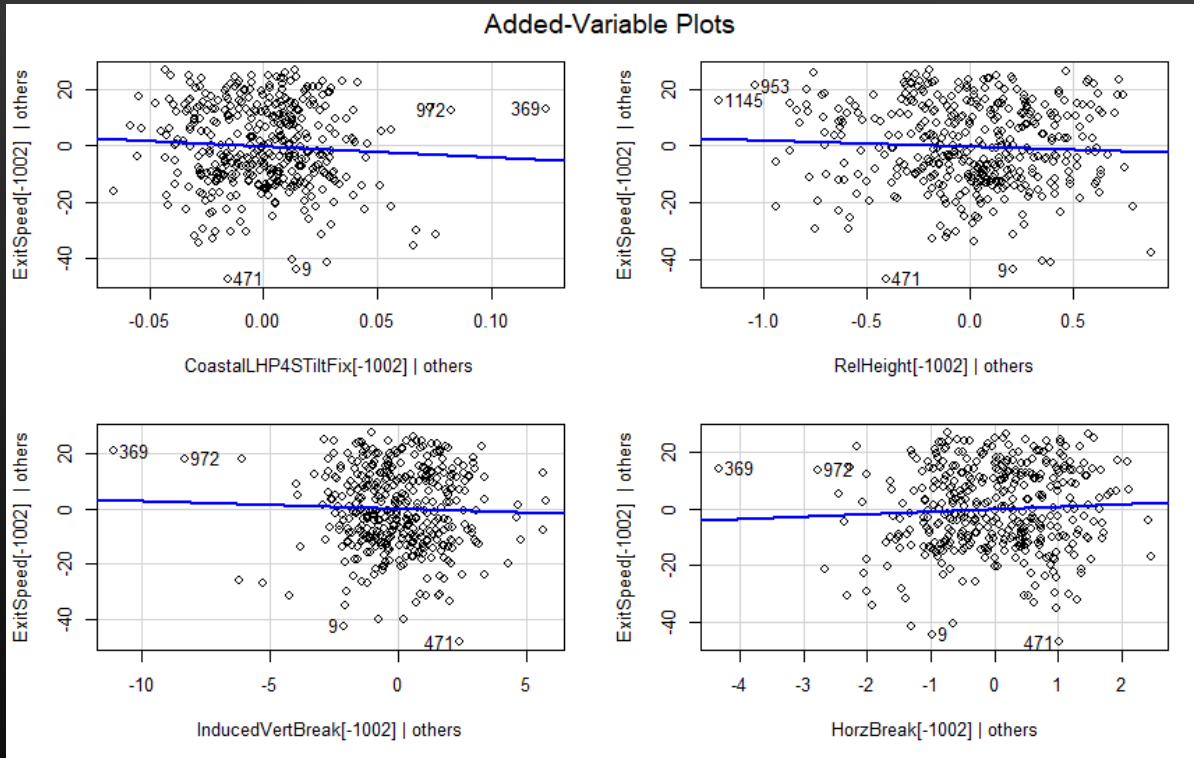


<https://www.drivelinebaseball.com/2019/09/mastering-the-axis-of-rotation-a-thorough-review-of-spin-axis-in-three-dimensions/>

-Measured on a clock-like axis and measures the spin direction of a pitch.

-Also called Spin Axis

# ASSUMPTIONS- ADDED VARIABLE PLOTS

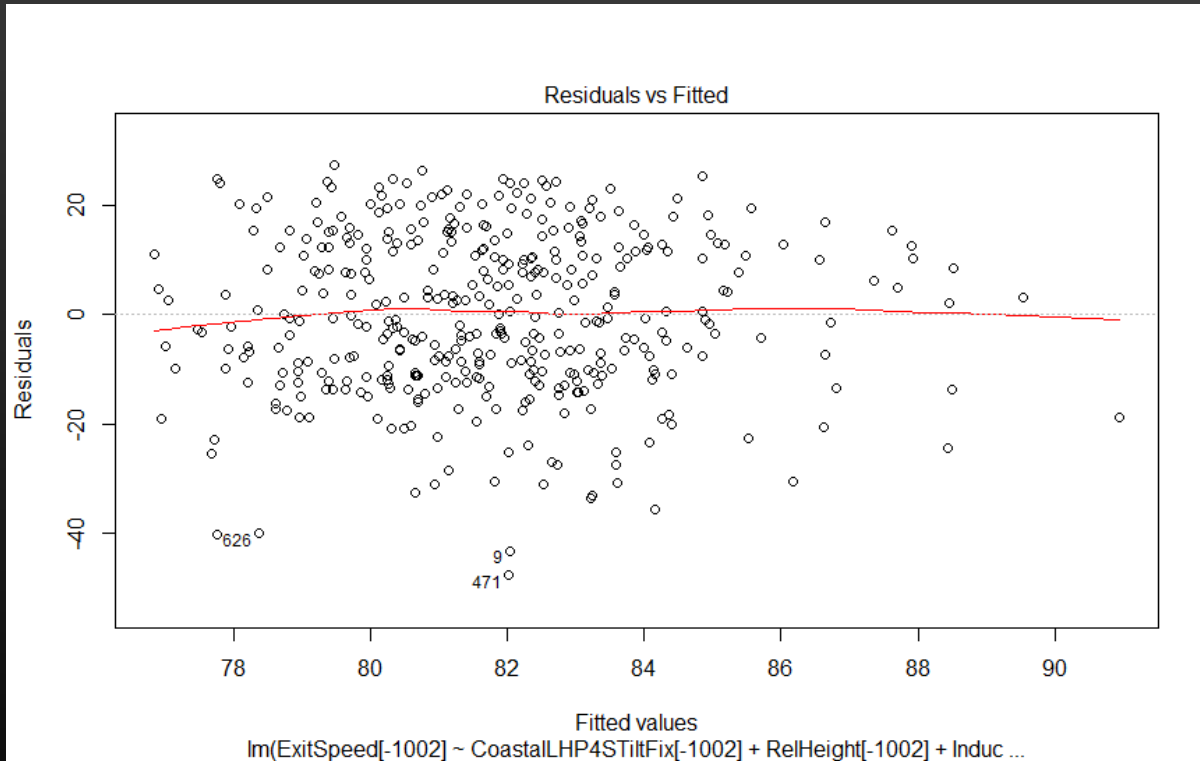


-Tests whether each variable adds new information to the model

-Slope of 0 means no information is being contributed by that factor.

-Larger slope means more information that a variable is adding to the model.

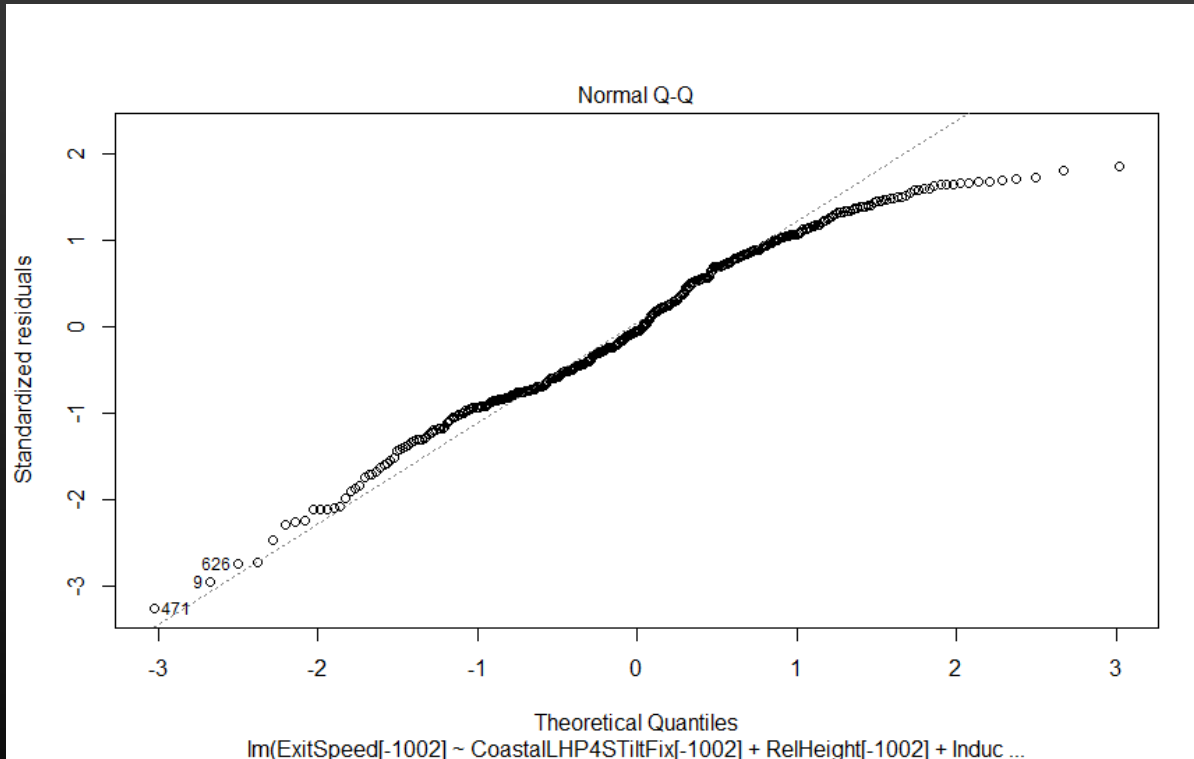
# ASSUMPTIONS- RESIDUALS VS. FITTED PLOTS



-Data must appear random, key is to not observe a funnel shape or any discernable pattern.

-Checks for constant variance, as non-constant variance implies a lack of fit.

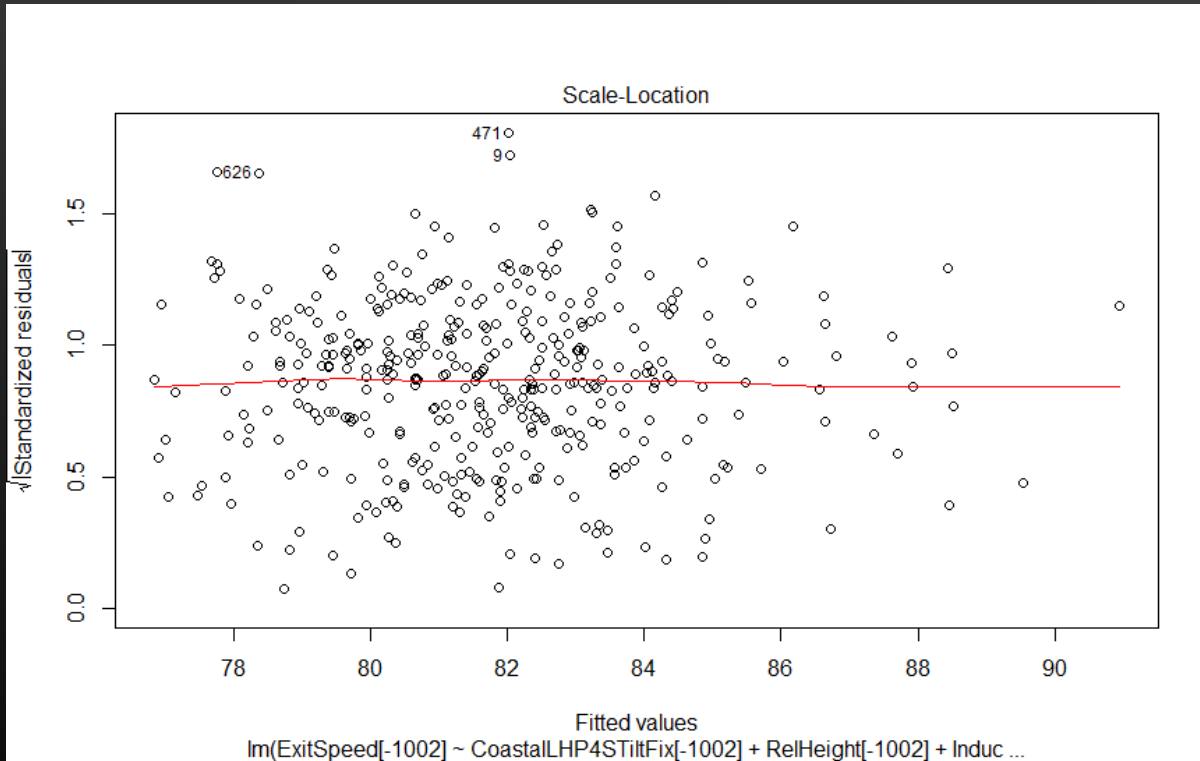
# ASSUMPTIONS- NORMAL PROBABILITY PLOT



-Produces a straight line if all error is distributed normally; however, with a large enough sample size the line may deviate from linear and still be accepted.

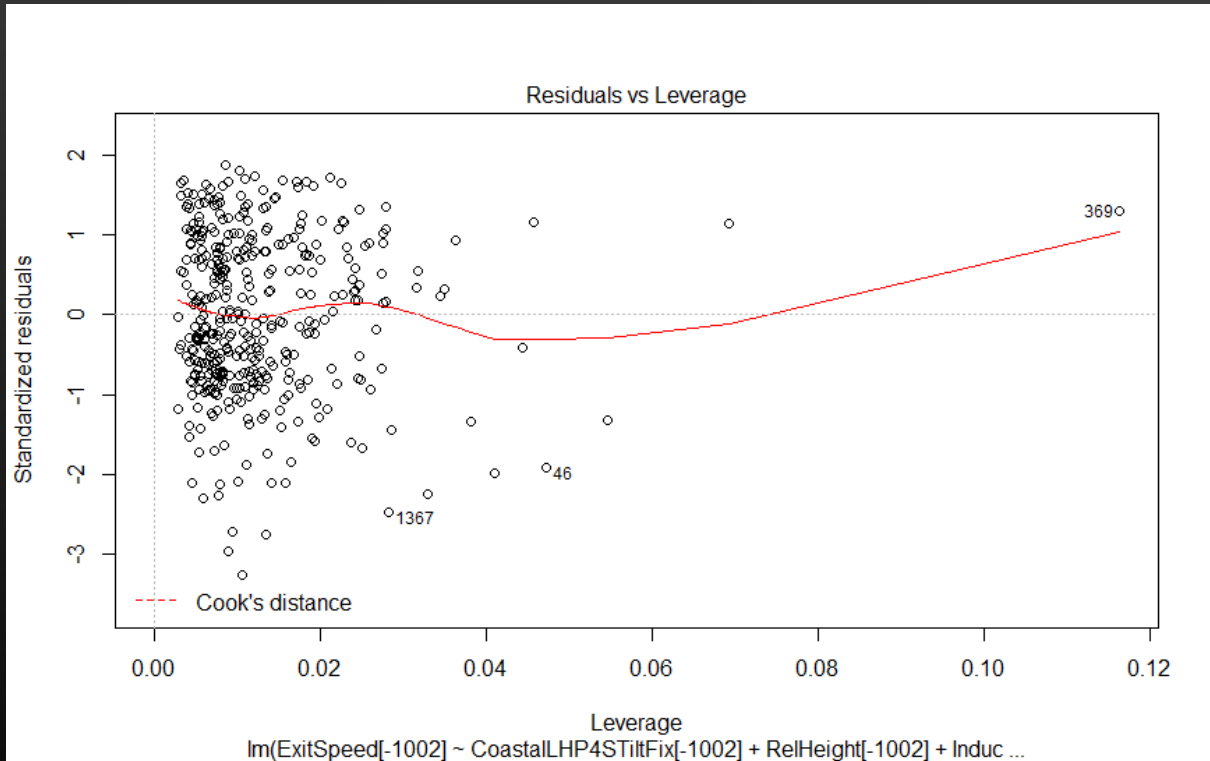


# ASSUMPTIONS- SCALE LOCATION PLOT



-Residuals are spread equally along the range of predictors and like the normal probability plot, should appear random, with no discernable pattern.

# ASSUMPTIONS- COOK'S DISTANCE PLOT



-Identifies leverage points within the data.

-A general rule in interpreting Cook's distance is that any value with a distance greater than 1 is influential and should be investigated.

# ASSUMPTIONS- VARIANCE INFLATION FACTOR (VIF)

	<code>vif(LHP4STIHR.mod)</code>	CoastalLHP4StiltFix[-1002]	RelHeight[-1002]	InducedVertBreak[-1002]	HorzBreak[-1002]
	9.448746	1.157054	2.106317	10.254556	

-Shows whether or not some variables can be written as linear combinations of the other variables being tested.

-Any vif under 15 for a variable is considered acceptable.



# IMAGE CREDITS

<https://giphy.com/gifs/looks-towards-fastball-7PFssIFdPil0g>

<http://i.imgur.com/vb9GLRC.gif>

<https://plus.maths.org/content/fly-walks-round-football>

<https://www.drivelinebaseball.com/2019/09/mastering-the-axis-of-rotation-a-thorough-review-of-spin-axis-in-three-dimensions/>

<https://lehmansbaseball.wordpress.com/2016/01/14/custom-vs-one-size-fits-all-throwing-mechanics/>

<https://giphy.com/gifs/comments-changeup-strasburg-115RAHRXu4zJzG>

