

THIS IS WHY PEOPLE SHOULD LEARN STATISTICS

WE MUST TAKE ANY ACTION AND PAY ANY COST TO LIMIT THE RISK OF A TERRORIST ATTACK!



LATER...

WOULD YOU LIKE ANY ADDED SAFETY FEATURES ON YOUR CAR?

NAH. TOO EXPENSIVE.



# Statistics and psychology in science

Quarknet 2017  
Spencer Chang

Credit: [smbc-comics.com](http://smbc-comics.com)





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## Physics Letters B

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# Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC <sup>☆</sup>

**ATLAS Collaboration <sup>☆</sup>**

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*Article history:*

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Accepted 11 August 2012

Available online 14 August 2012

Editor: W.-D. Schlatter

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# Outline

- What constitutes a discovery in particle physics?
- Statistics and psychological effects
- Broader scientific and everyday life impacts

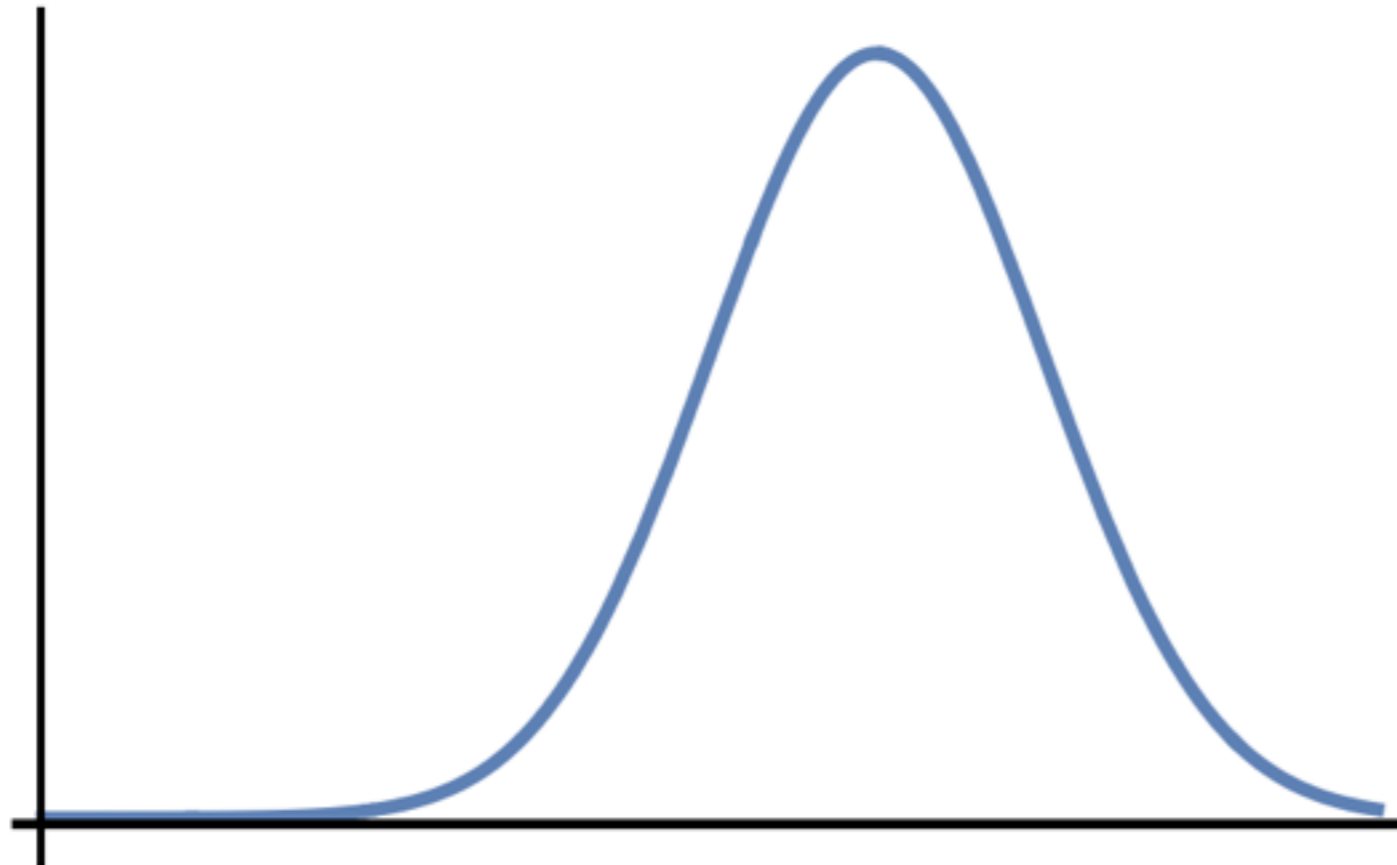


# Finding Something New

When trying to find something new (in science), you want to be convinced its broken

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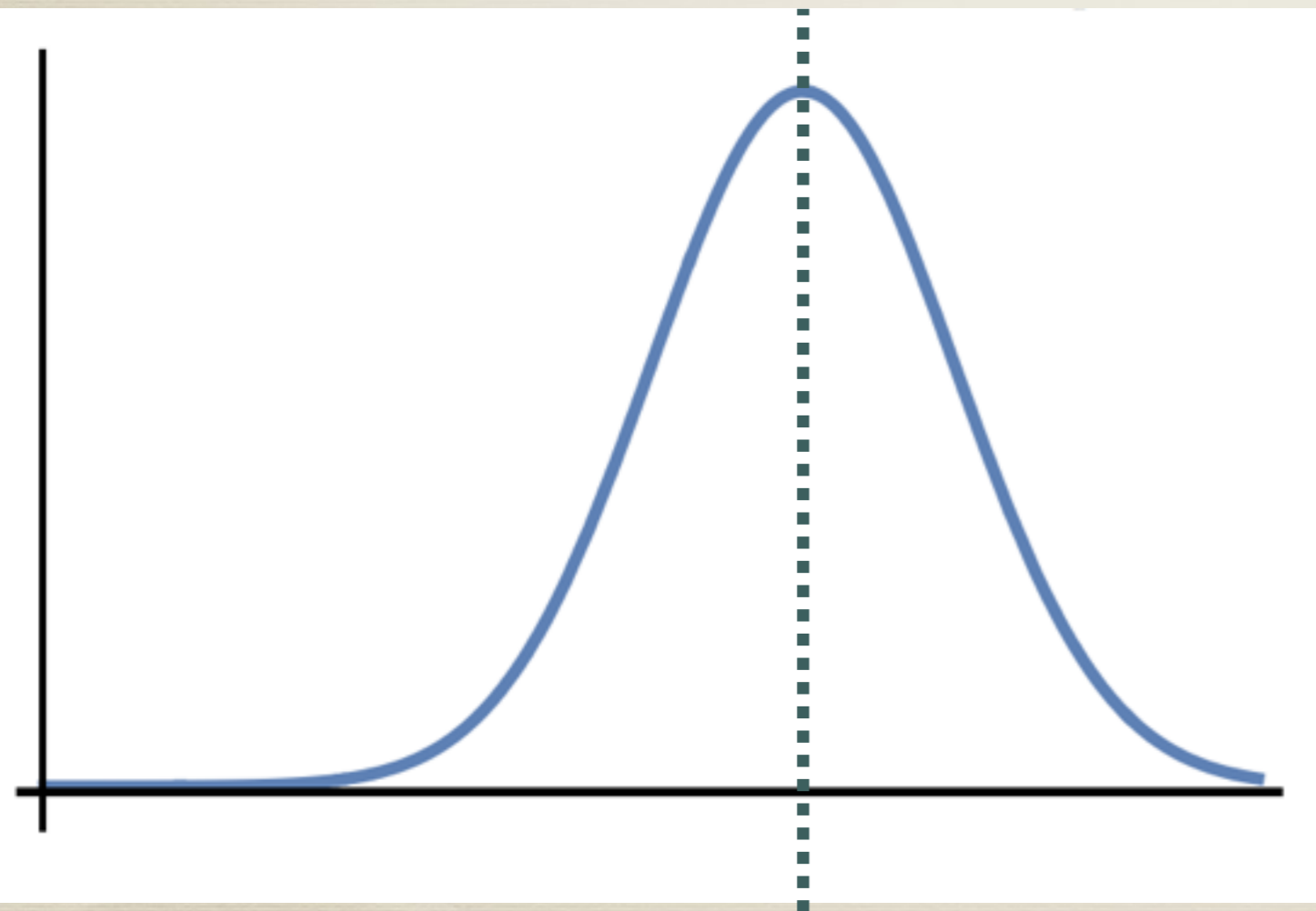


Current theory predicts  
a distribution for an  
outcome (e.g. # of events)



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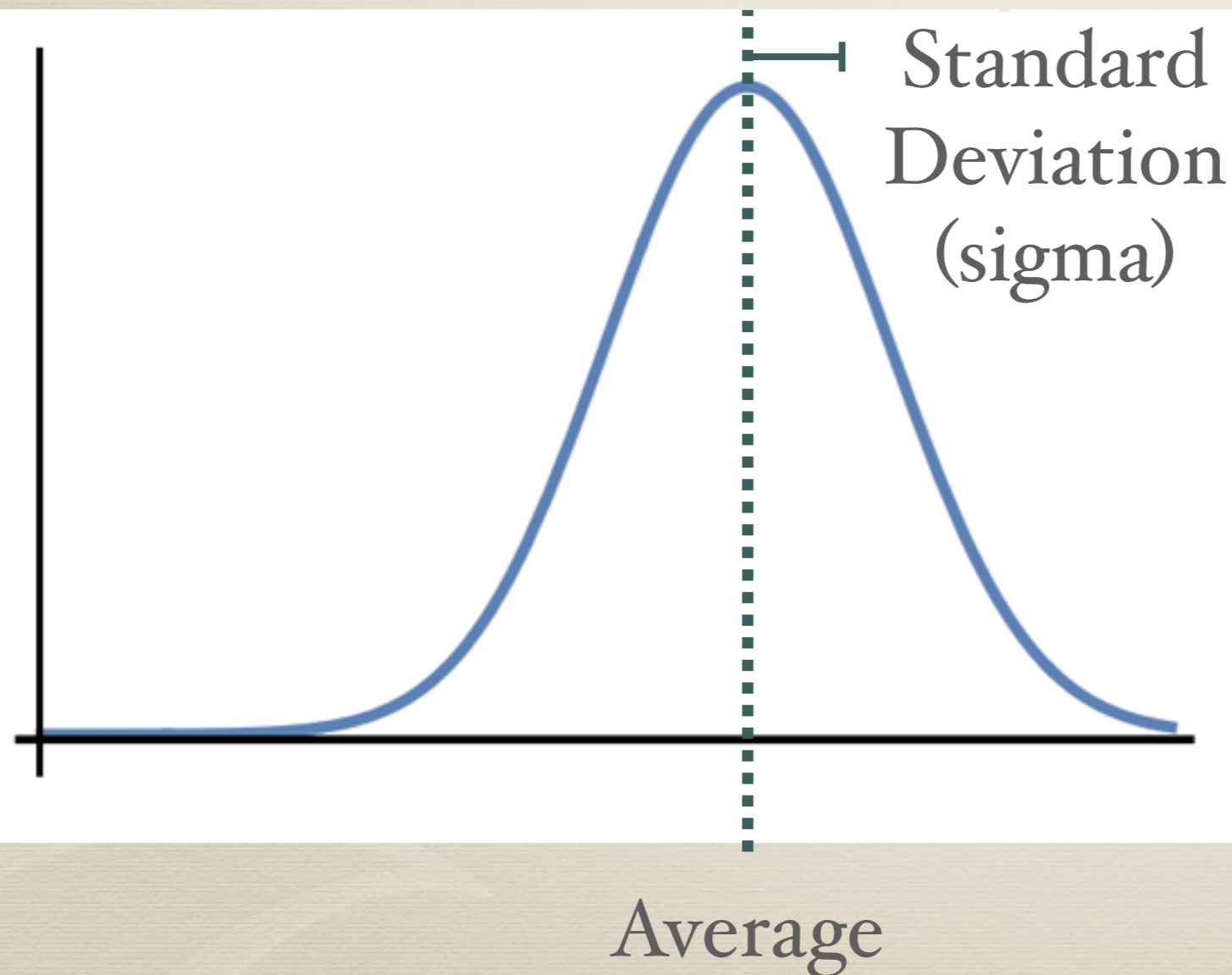
Average

Current theory predicts  
a distribution for an  
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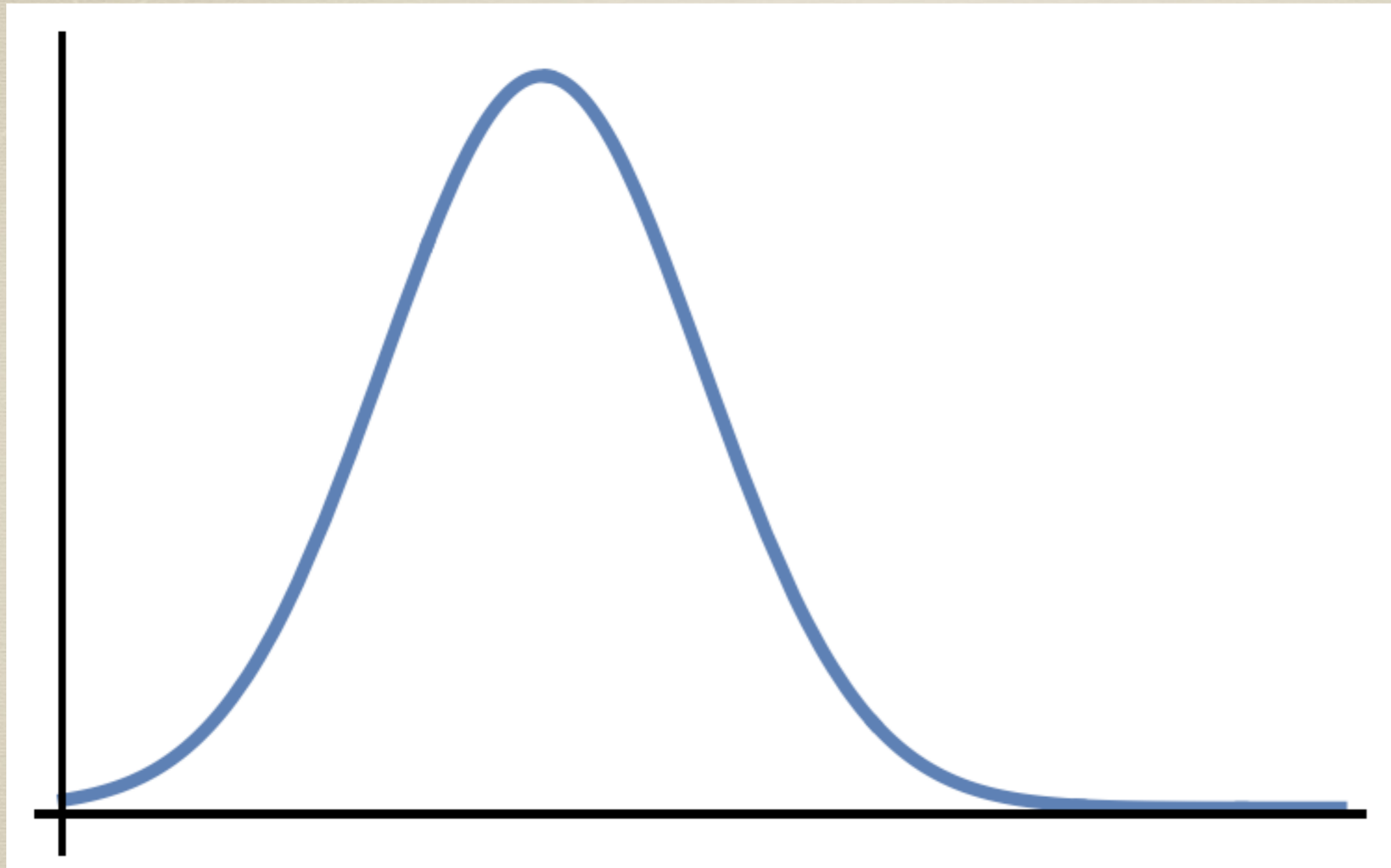
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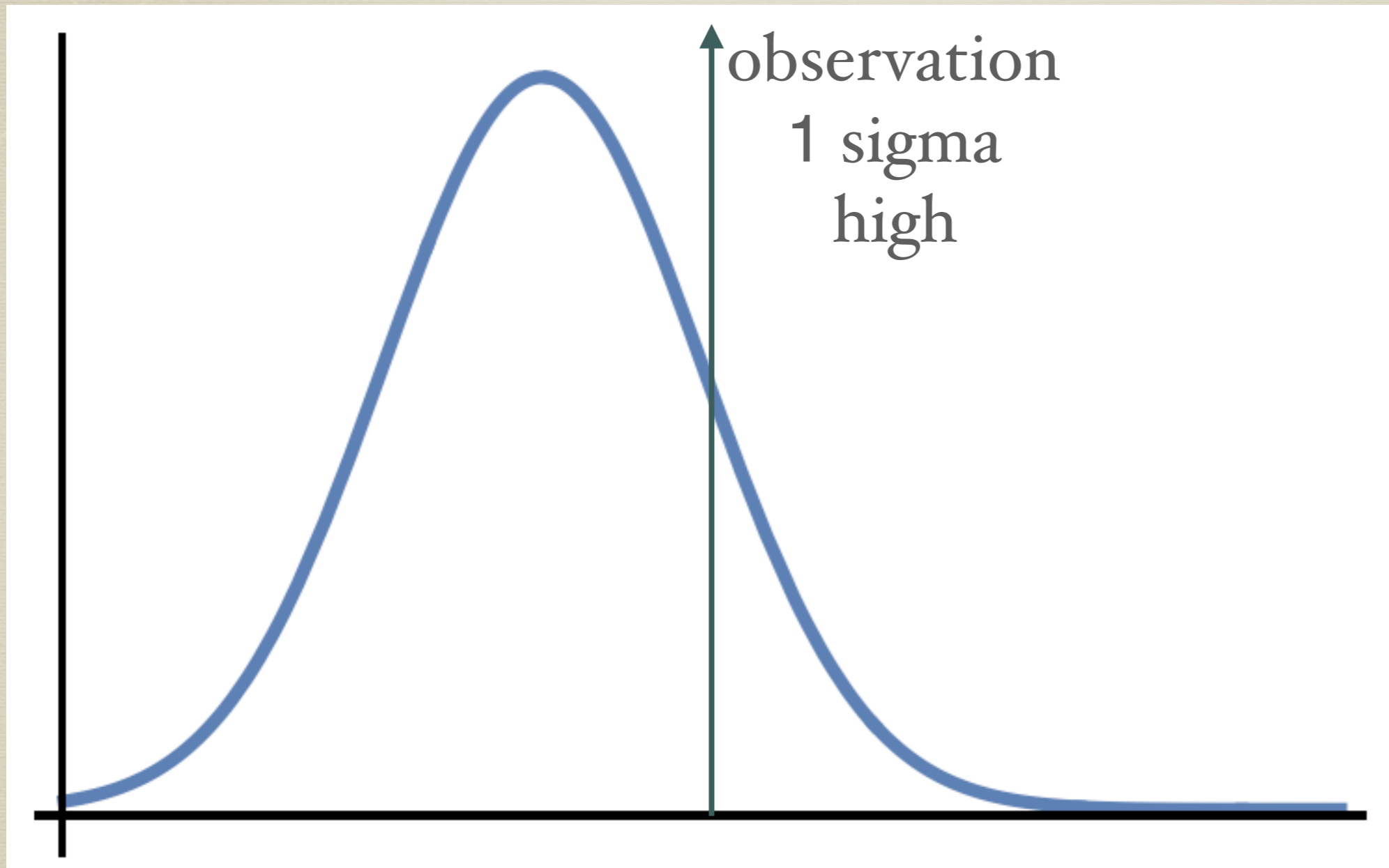
# The Breaking Point



# of events

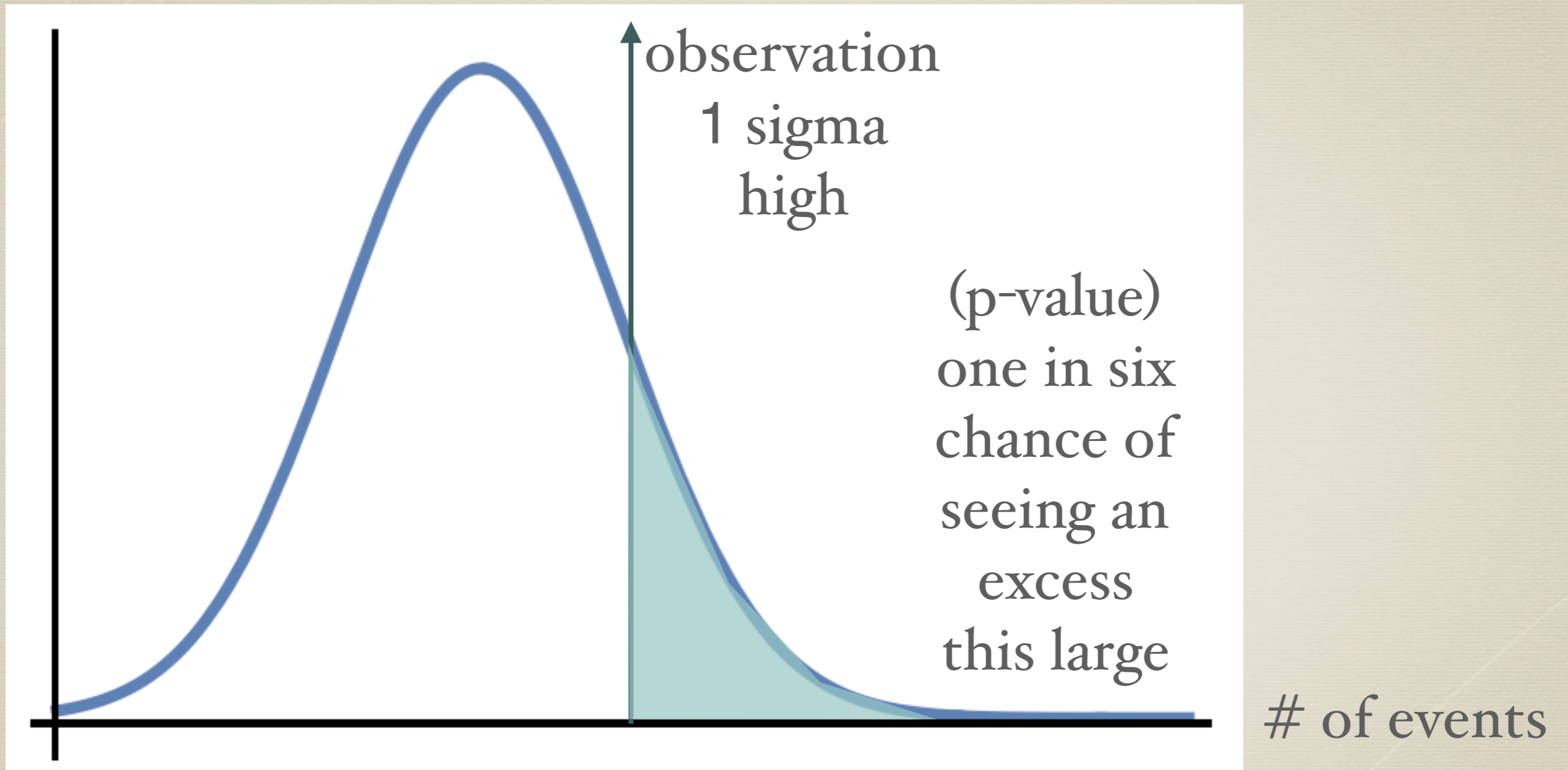


# The Breaking Point



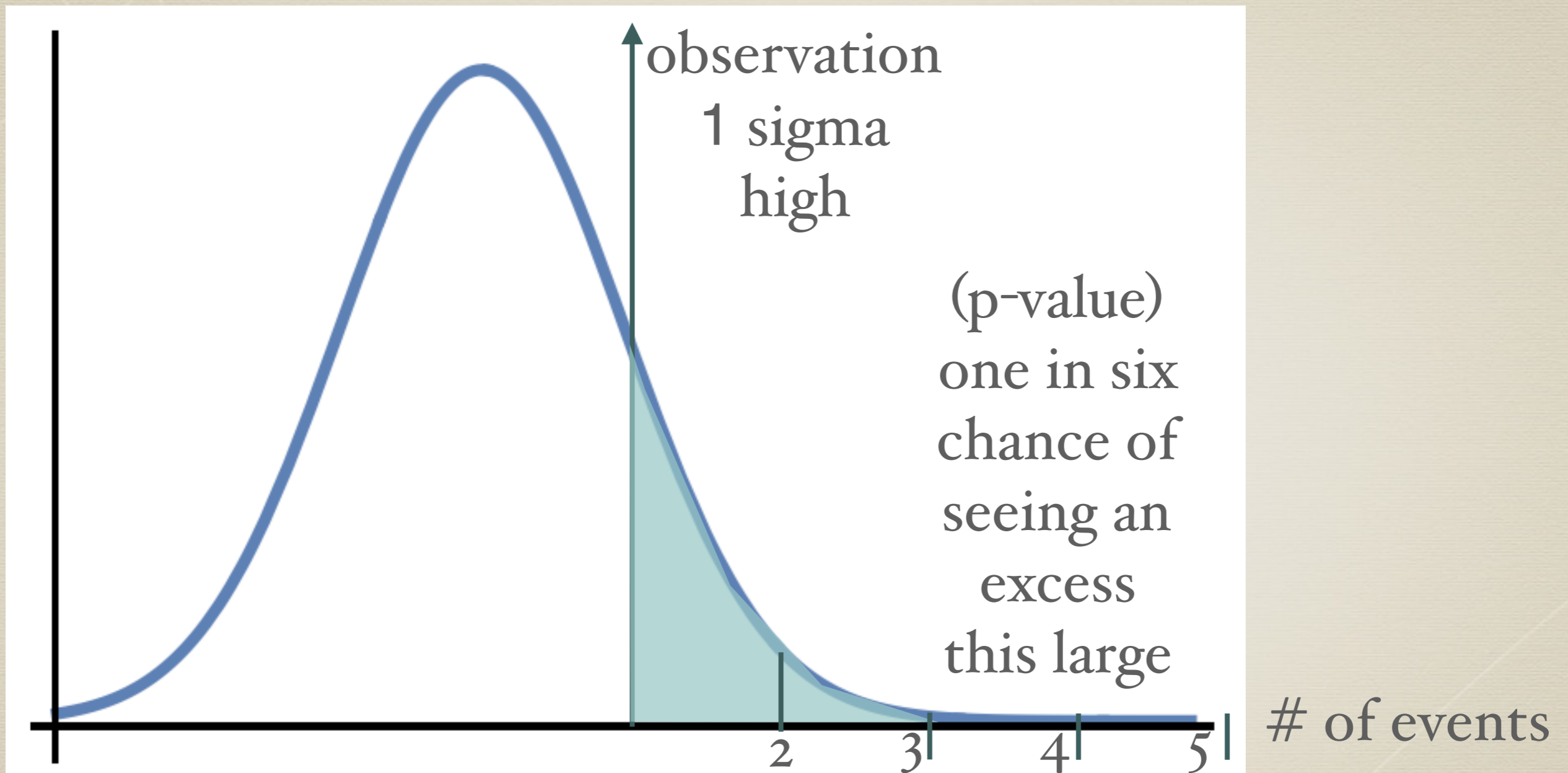
# of events

# The Breaking Point





# The Breaking Point



As one increases the deviation, chance drops  
2 sigma = one in 40, 3 sigma = 1 in 740, 4 sigma = 1 in 30k  
5 sigma = 1 in 30 million

# Particle Physics Discovery Convention

Convention for when a theory breaks and you see a new effect  
is **field** dependent

In particle physics, it is convention for five sigma,  
i.e. only in a one in 30 million chance of making a mistake  
and there is no new effect

In other fields, two sigma is standard (e.g. psychology),  
only a chance of one in 40 that it is wrong



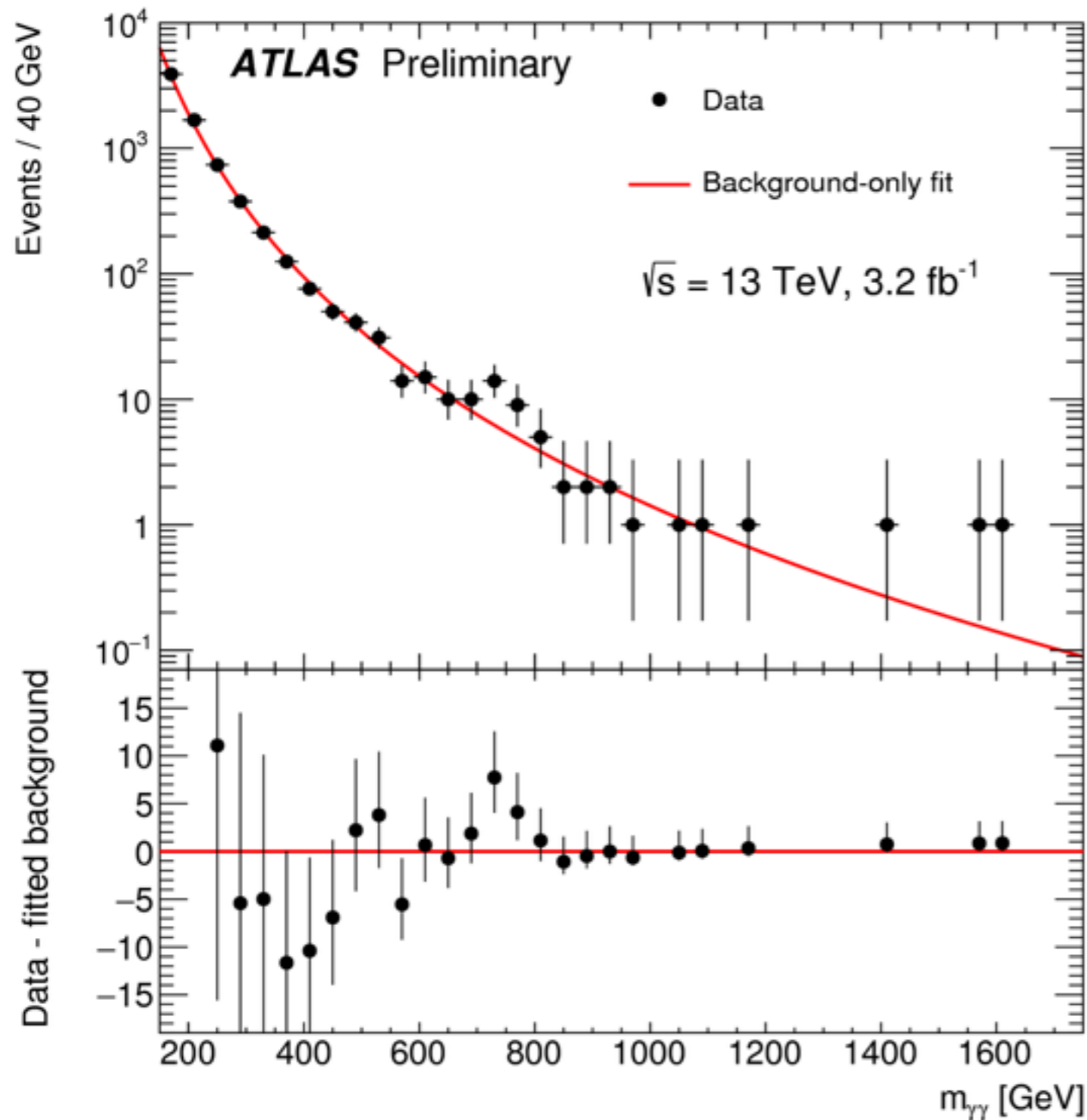
# Why this standard?

- Historical: 3 sigma effects go away
- Look elsewhere effect
- p-hacking

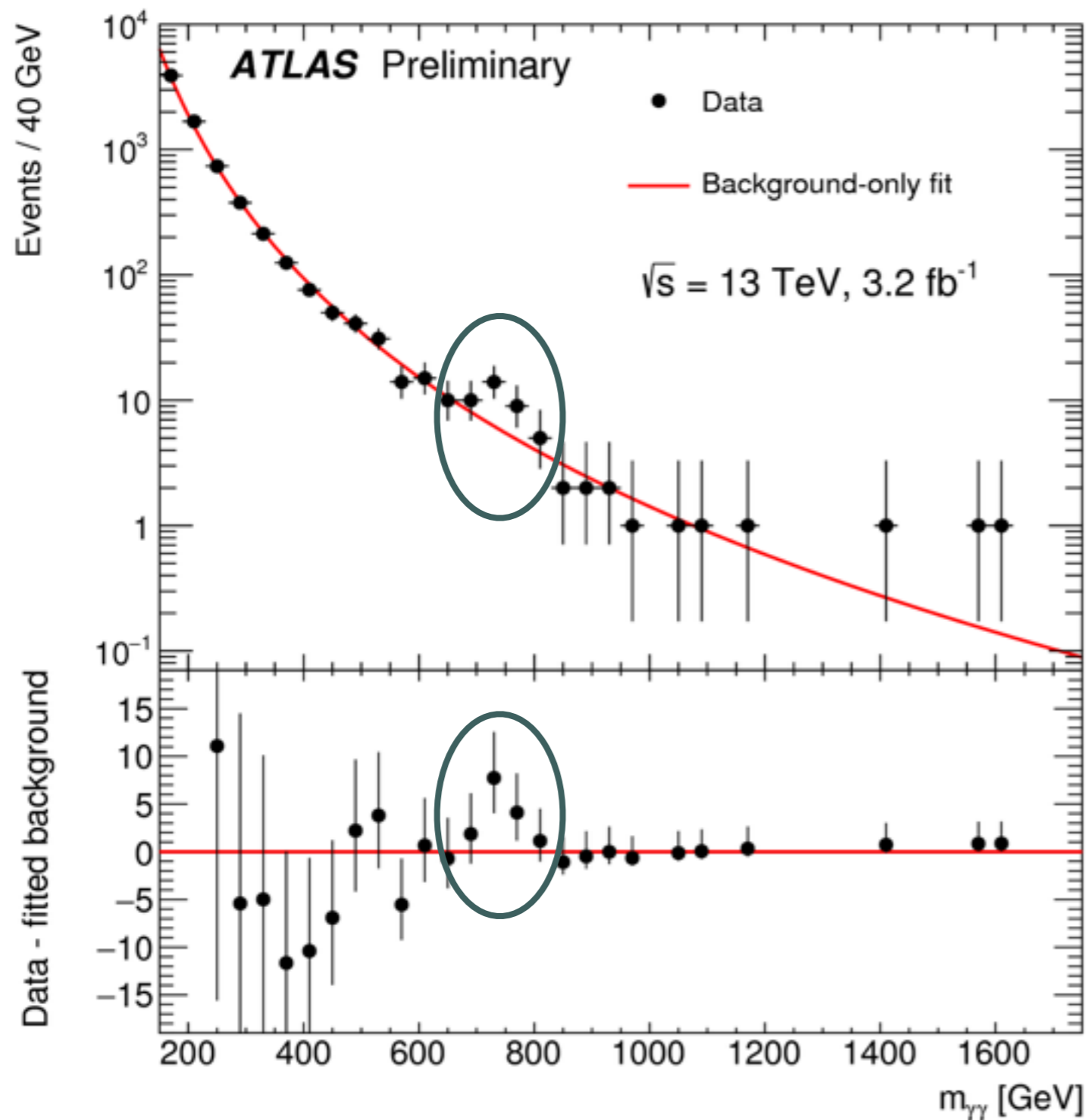
Many examples of 3 sigma effects (only one in 1000)  
going away



# Many examples of 3 sigma effects (only one in 1000) going away



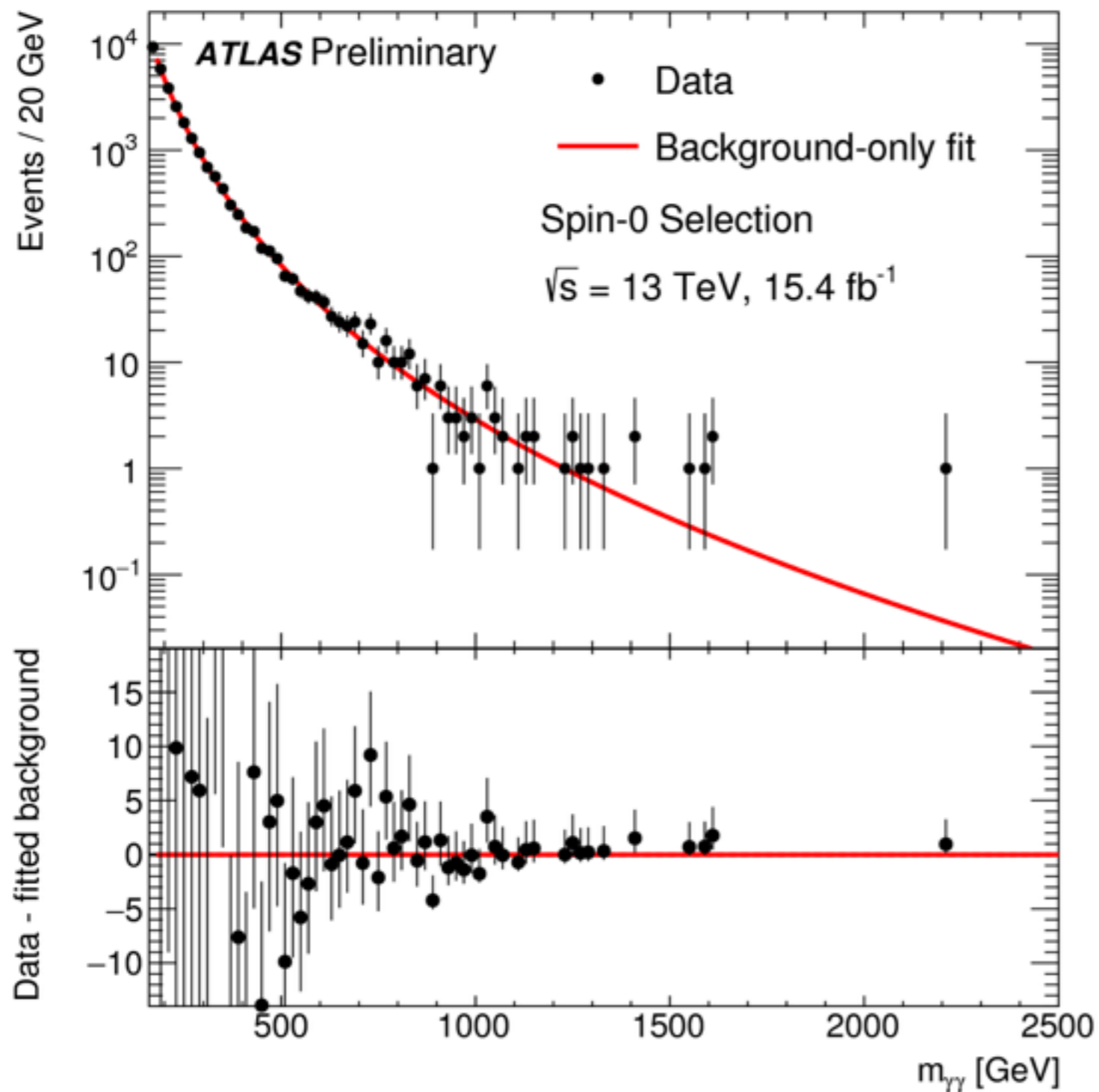
# Many examples of 3 sigma effects (only one in 1000) going away



Dec. 2015 ATLAS  
and CMS saw a  
nearly 4 sigma excess  
(one in 10000)



# Many examples of 3 sigma effects (only one in 1000) going away



Dec. 2015 ATLAS  
and CMS saw a  
nearly 4 sigma excess  
(one in 10000)

With more data  
the excess has gone  
away

This was more  
extreme, but shows  
why 2, 3 sigmas are  
only interesting, but  
nothing concrete

How does this happen?



# Look Elsewhere Effect

Rare events are less rare if you are looking in several places

# Look Elsewhere Effect

Rare events are less rare if you are looking in several places

Example: It is rare to win the lottery, but you know somebody who's won the lottery, how rare is that?



# Look Elsewhere Effect

Rare events are less rare if you are looking in several places

Example: It is rare to win the lottery, but you know somebody who's won the lottery, how rare is that?

It might be more common because you know many people also you might have been also surprised if somebody you knew won a Nobel prize, was in the NBA, a rock star, etc....

JELLY BEANS  
CAUSE ACNE!

SCIENTISTS!  
INVESTIGATE!

BUT WE'RE  
PLAYING  
MINECRAFT!  
... FINE.



WE FOUND NO  
LINK BETWEEN  
JELLY BEANS AND  
ACNE ( $P > 0.05$ ).



THAT SETTLES THAT.

I HEAR IT'S ONLY  
A CERTAIN COLOR  
THAT CAUSES IT.

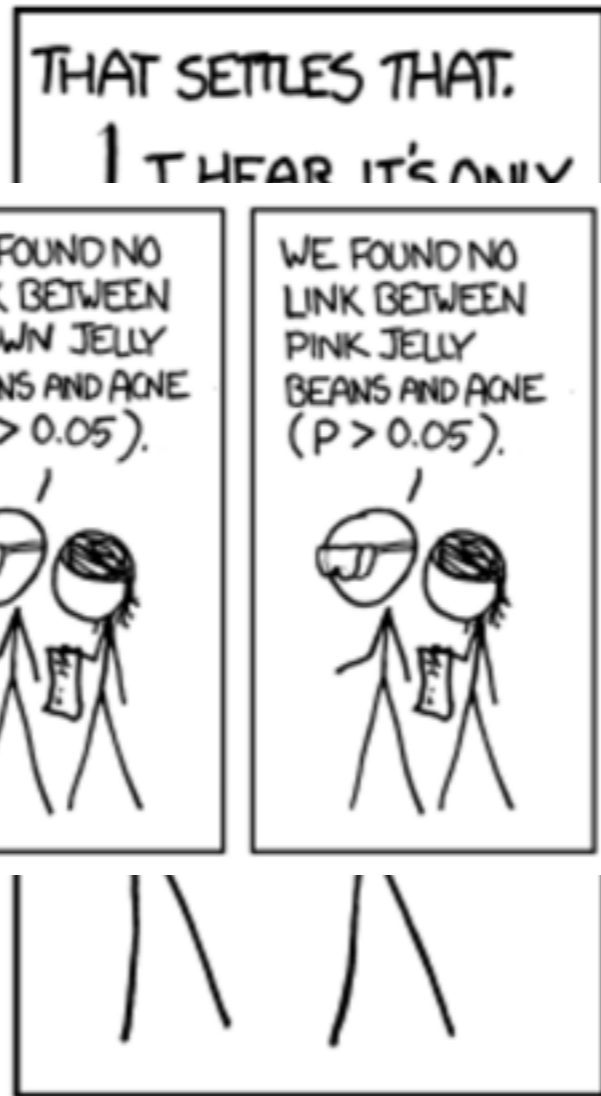
SCIENTISTS!

BUT  
MIIINECRAFT!

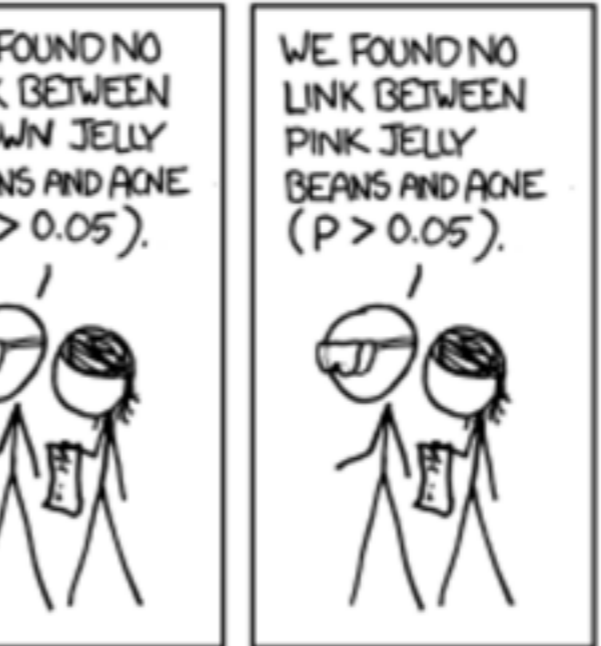


Credit: xkcd.com





THAT SETTLES THAT.  
I HEAR IT'S ONLY



JELLY BEANS CAUSE ACNE!

SCIENTISTS!  
INVESTIGATE!

BUT WE'RE PLAYING MINECRAFT!  
... FINE.

WE FOUND NO LINK BETWEEN LINK BETWEEN


THAT SETTLES THAT.  
I HEAR IT'S ONLY

WE FOUND NO LINK BETWEEN PURPLE JELLY BEANS AND ACNE ( $P > 0.05$ ).

WE FOUND NO LINK BETWEEN BROWN JELLY BEANS AND ACNE ( $P > 0.05$ ).

WE FOUND NO LINK BETWEEN PINK JELLY BEANS AND ACNE ( $P > 0.05$ ).

WE FOUND NO LINK BETWEEN BLUE JELLY BEANS AND ACNE ( $P > 0.05$ ).



WE FOUND NO LINK BETWEEN TEAL JELLY BEANS AND ACNE ( $P > 0.05$ ).



WE FOUND NO LINK BETWEEN SALMON JELLY BEANS AND ACNE ( $P > 0.05$ ).



WE FOUND NO LINK BETWEEN RED JELLY BEANS AND ACNE ( $P > 0.05$ ).



WE FOUND NO LINK BETWEEN TURQUOISE JELLY BEANS AND ACNE ( $P > 0.05$ ).



WE FOUND NO LINK BETWEEN MAGENTA JELLY BEANS AND ACNE ( $P > 0.05$ ).



WE FOUND NO LINK BETWEEN YELLOW JELLY BEANS AND ACNE ( $P > 0.05$ ).





JELLY BEANS CAUSE ACNE!

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MINECRAFT!  
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LINK BETWEEN

THAT SETTLES THAT.

I HEAR IT'S ONLY

WE FOUND NO  
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PURPLE JELLY  
BEANS AND ACNE  
( $P > 0.05$ ).

WE FOUND NO  
LINK BETWEEN  
BROWN JELLY  
BEANS AND ACNE  
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WE FOUND NO  
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PINK JELLY  
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SALMON JELLY  
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RED JELLY  
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WE FOUND NO  
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MAGENTA JELLY  
BEANS AND ACNE  
( $P > 0.05$ ).

WE FOUND NO  
LINK BETWEEN  
YELLOW JELLY  
BEANS AND ACNE  
( $P > 0.05$ ).

WE FOUND NO  
LINK BETWEEN  
GREY JELLY  
BEANS AND ACNE  
( $P > 0.05$ ).

WE FOUND NO  
LINK BETWEEN  
TAN JELLY  
BEANS AND ACNE  
( $P > 0.05$ ).

WE FOUND NO  
LINK BETWEEN  
CYAN JELLY  
BEANS AND ACNE  
( $P > 0.05$ ).

WE FOUND A  
LINK BETWEEN  
GREEN JELLY  
BEANS AND ACNE  
( $P < 0.05$ ).

WE FOUND NO  
LINK BETWEEN  
MAUVE JELLY  
BEANS AND ACNE  
( $P > 0.05$ ).

WHOA!



JELLY BEANS CAUSE ACNE!  
SCIENTISTS!  
INVESTIGATE!  
BUT WE'RE PLAYING MINECRAFT!  
... FINE.

WE FOUND NO LINK BETWEEN  
LINK BETWEEN

THAT SETTLES THAT.  
I HEAR IT'S ONLY

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WE FOUND NO LINK BETWEEN TAN JELLY BEANS AND ACNE ( $P > 0.05$ ).

WE FOUND NO LINK BETWEEN CYAN JELLY BEANS AND ACNE ( $P > 0.05$ ).

WE FOUND A LINK BETWEEN GREEN JELLY BEANS AND ACNE ( $P < 0.05$ ).  
WHOA!

WE FOUND NO LINK BETWEEN MAUVE JELLY BEANS AND ACNE ( $P > 0.05$ ).

WE FOUND NO LINK BETWEEN BEIGE JELLY BEANS AND ACNE ( $P > 0.05$ ).

WE FOUND NO LINK BETWEEN LILAC JELLY BEANS AND ACNE ( $P > 0.05$ ).

WE FOUND NO LINK BETWEEN BLACK JELLY BEANS AND ACNE ( $P > 0.05$ ).

WE FOUND NO LINK BETWEEN PEACH JELLY BEANS AND ACNE ( $P > 0.05$ ).

WE FOUND NO LINK BETWEEN ORANGE JELLY BEANS AND ACNE ( $P > 0.05$ ).



JELLY BEANS CAUSE ACNE!  
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INVESTIGATE!  
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LINK BETWEEN

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WE FOUND NO LINK BETWEEN RED JELLY BEANS AND ACNE ( $P > 0.05$ ).


**News**

**GREEN JELLY BEANS LINKED TO ACNE!**

**95% CONFIDENCE**

**ONLY 5% CHANCE OF COINCIDENCE!**

**SCIENTISTS...**



WE FOUND A LINK BETWEEN GREEN JELLY BEANS AND ACNE ( $P < 0.05$ ).

WE FOUND NO LINK BETWEEN MAUVE JELLY BEANS AND ACNE ( $P > 0.05$ ).

WE FOUND NO LINK BETWEEN BEIGE JELLY BEANS AND ACNE ( $P > 0.05$ ).

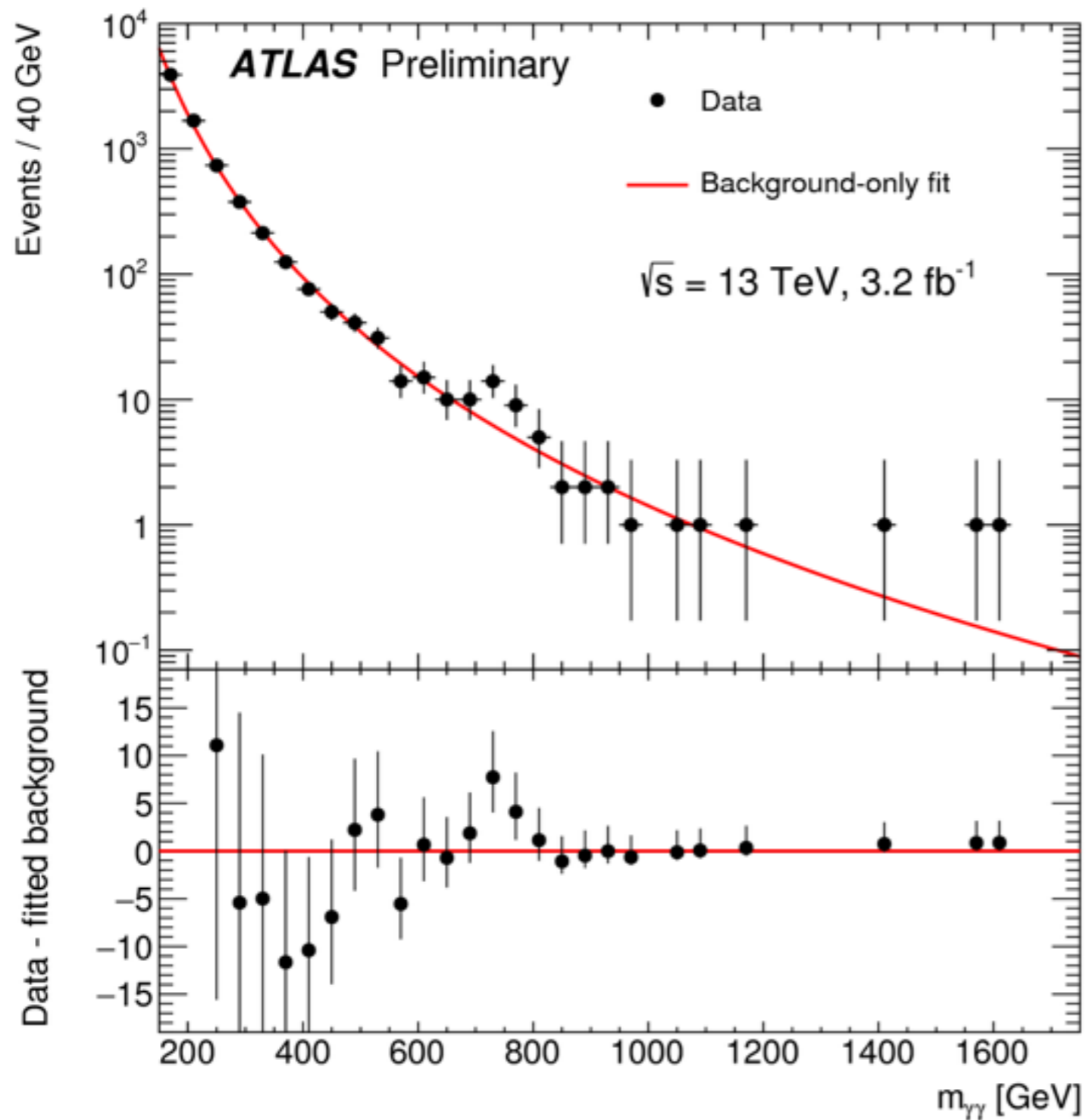
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WHOA!

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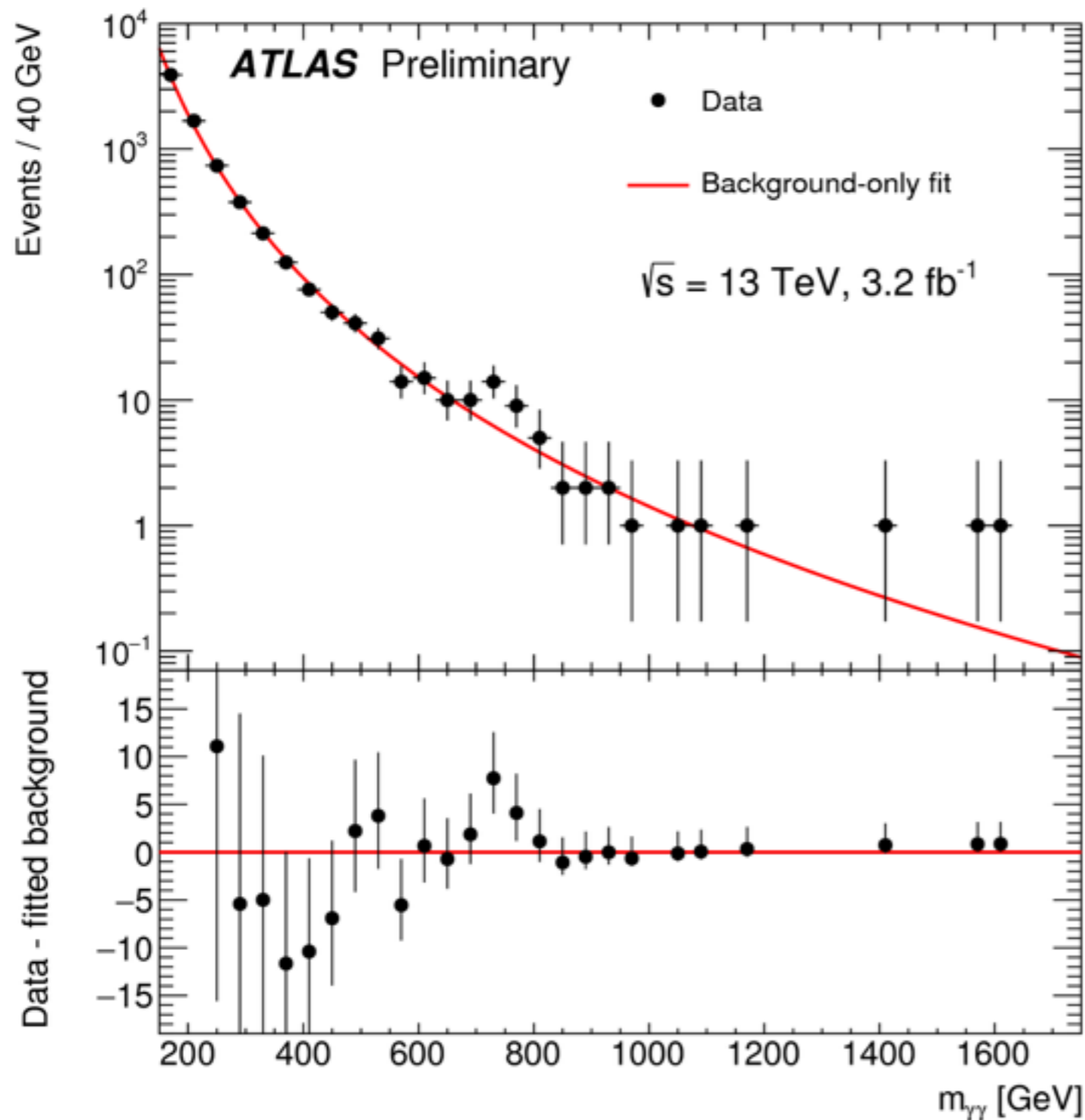
# Look Elsewhere Effect



Without a predicted mass, excess in any bin would have been exciting



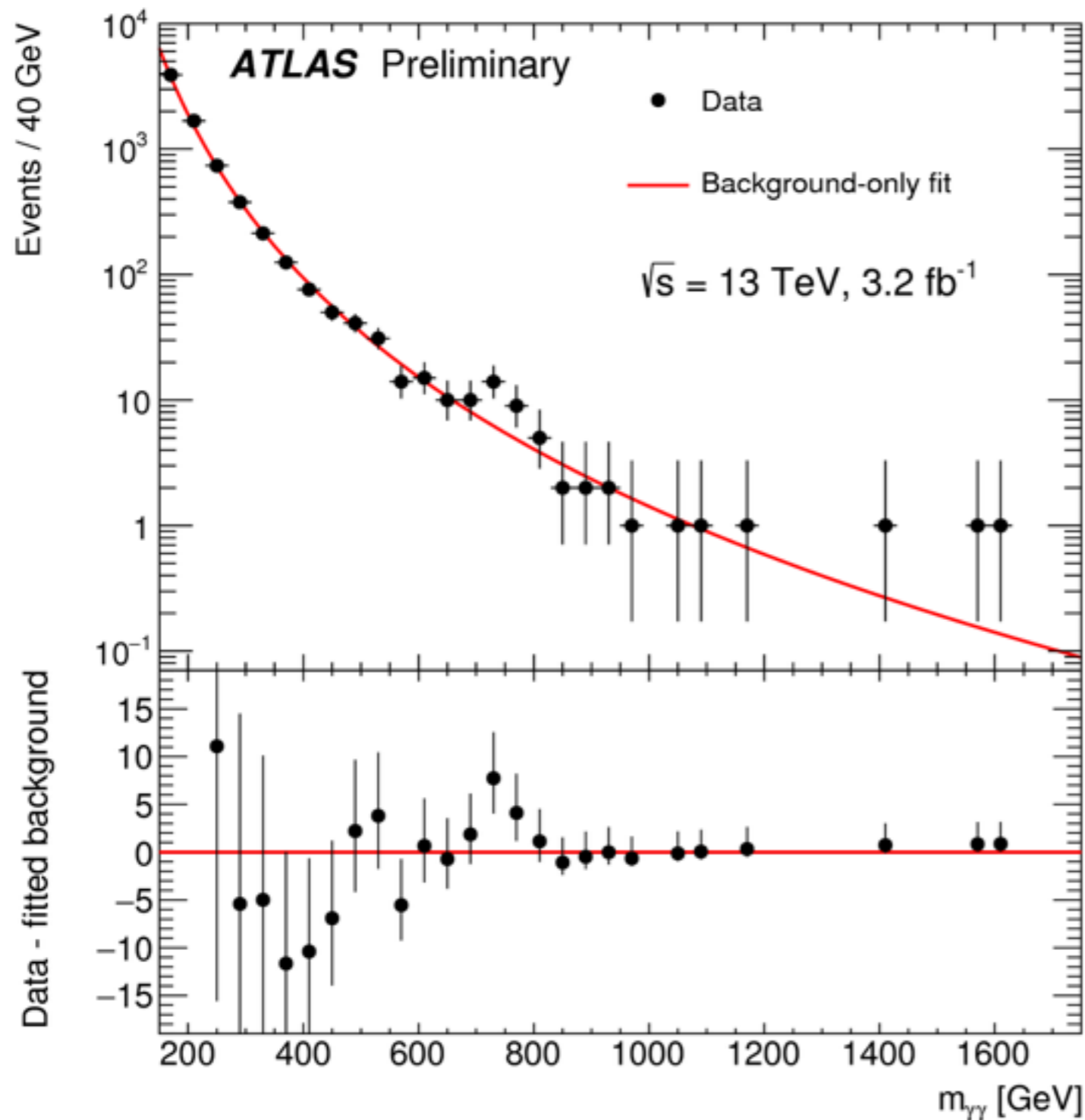
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So in a given search, there is also a "global" p-value, taking into look elsewhere

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Without a predicted mass, excess in any bin would have been exciting

So in a given search, there is also a "global" p-value, taking into look elsewhere

However, there are many searches, so 5 sigma is a conservative standard to be extra sure



# P-hacking

Another potential worry is p-hacking, continuing to look for significant effects until one finds one (e.g. testing a new color of jelly bean until one finds a statistically significant result)

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In particle physics, this used to happen because people would build up an excess after seeing the data (e.g. throwing out events, restricting to certain final state particles)

Now, experimental analyses are often blinded, with analysis procedure set before "opening" the box

## SCIENCE

# Many Psychology Findings Not as Strong as Claimed, Study Says

By BENEDICT CAREY AUG. 27, 2015

The past several years have been bruising ones for the credibility of the social sciences. A star social psychologist was caught fabricating data, leading to more than 50 retracted papers. A top journal published a study supporting the existence of ESP that was widely criticized. The journal *Science* pulled a political science paper on the effect of gay canvassers on voters' behavior because of concerns about faked data.

# Replication Crisis



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# Replication Crisis

## BAD SCIENCE

[nymag.com](http://nymag.com)

## A Popular Diet-Science Lab Has Been Publishing Really Shoddy Research

By Jesse Singal

The **Food and Brand Lab** at Cornell University publishes a huge amount of research about how people perceive, consume, and think about food. The lab covers **subjects** ranging from **seasonal trends in weight gain** to **how happy music influences employees**, and its director, the marketing and consumer behavior expert **Brian Wansink**, regularly touts his lab's research during his frequent media appearances, focusing particularly on the behavioral science underlying people's consumption habits.

# Recent Embarrassments

Science & Environment

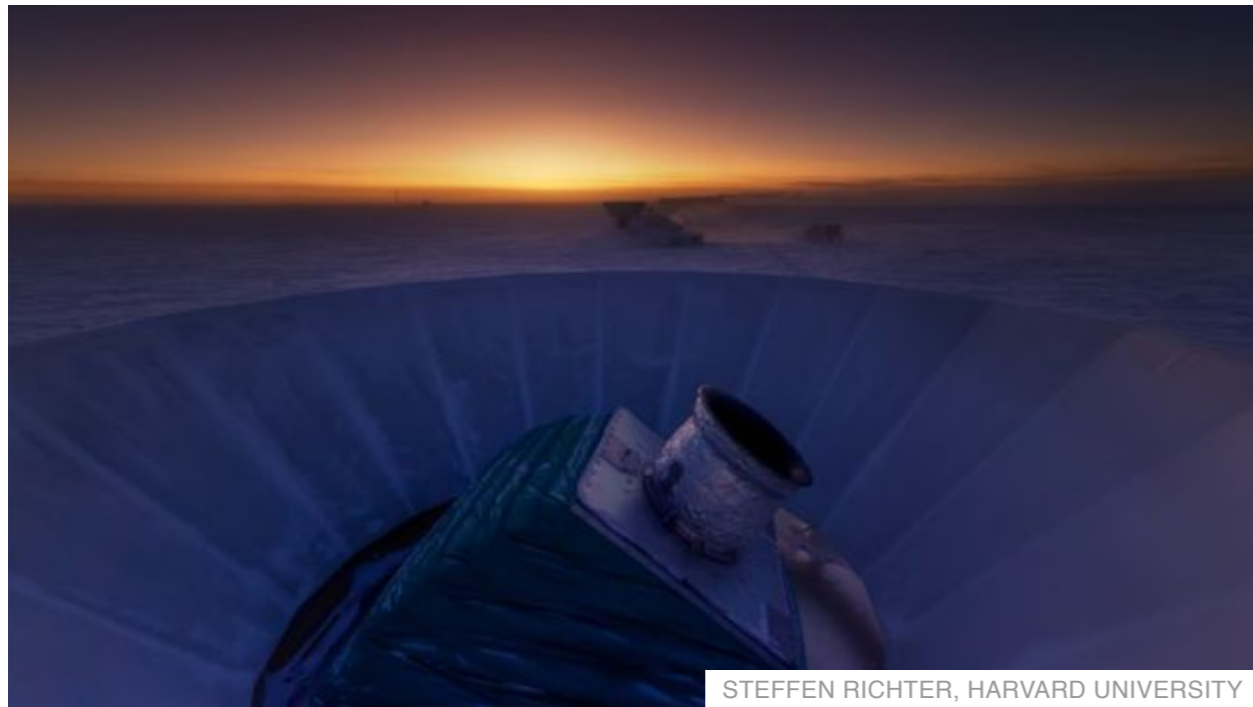
BBC

## Cosmic inflation: 'Spectacular' discovery hailed

By Jonathan Amos

Science correspondent, BBC News

17 March 2014 | [Science & Environment](#)



STEFFEN RICHTER, HARVARD UNIVERSITY



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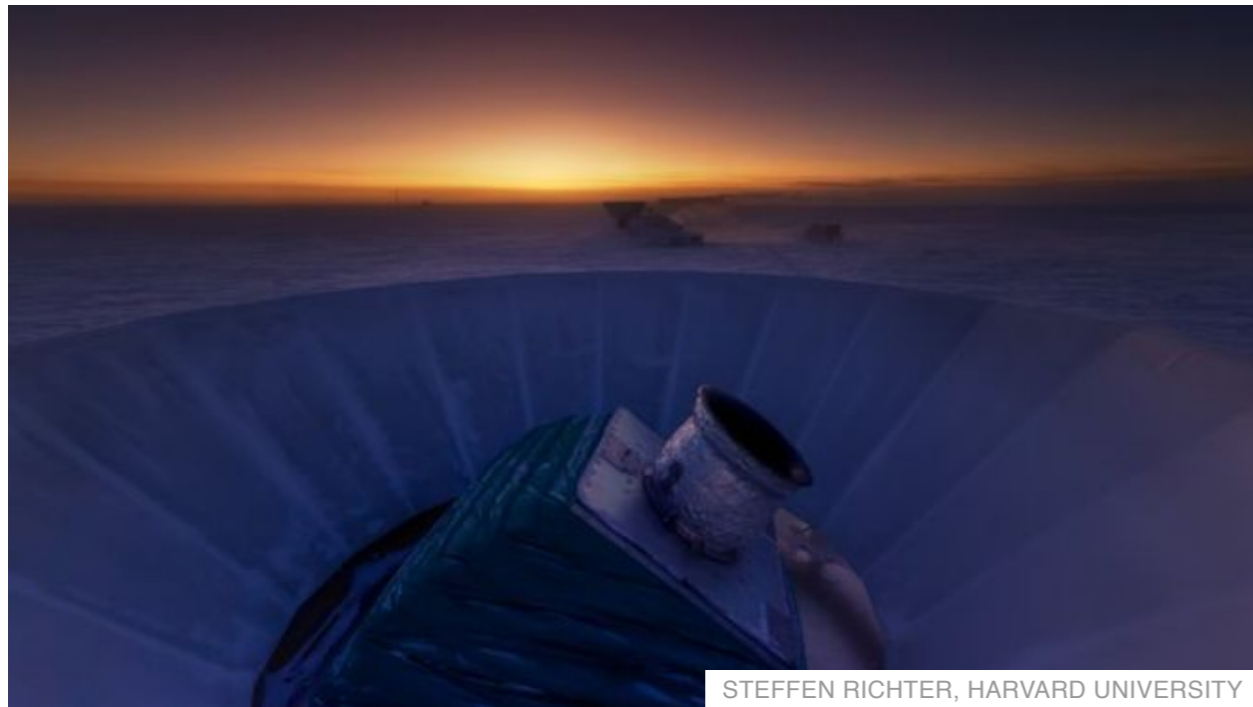
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STEFFEN RICHTER, HARVARD UNIVERSITY

Background from galactic  
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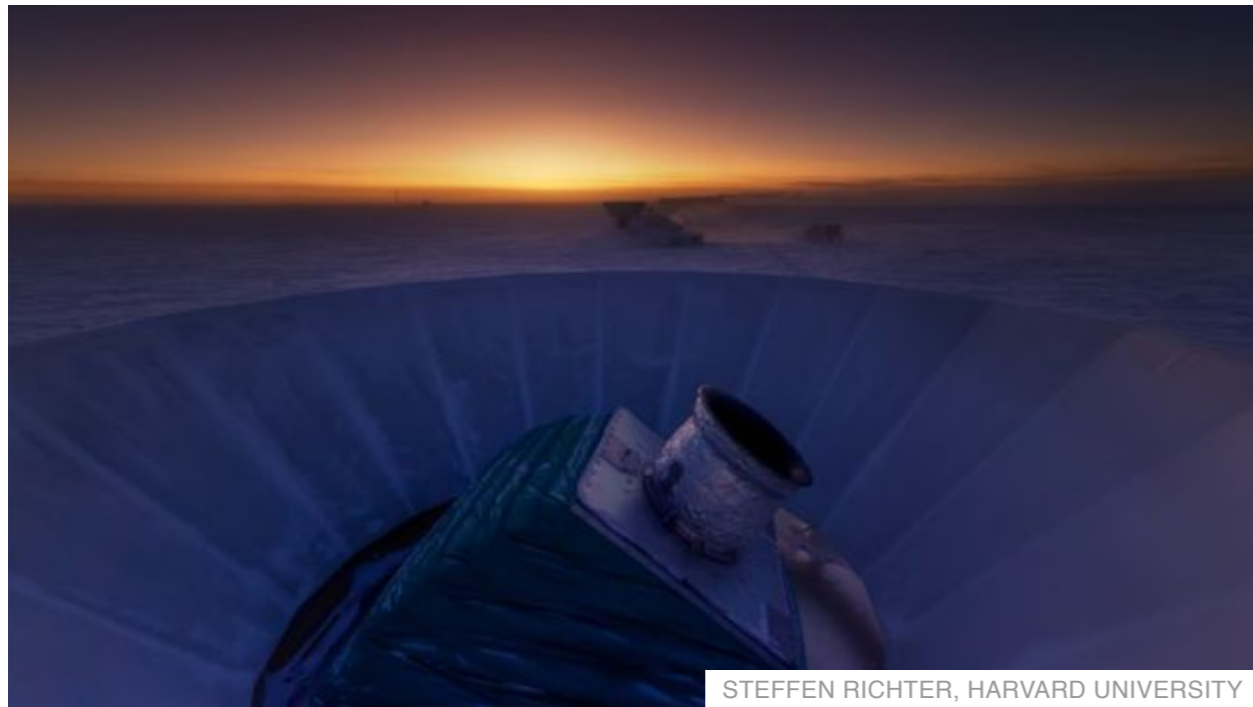
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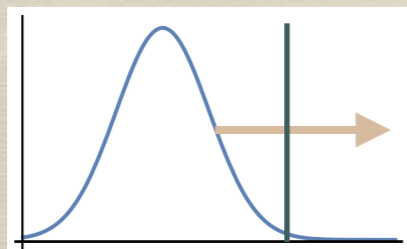
Science correspondent, BBC News

17 March 2014 | [Science & Environment](#)



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# Recent Embarrassments

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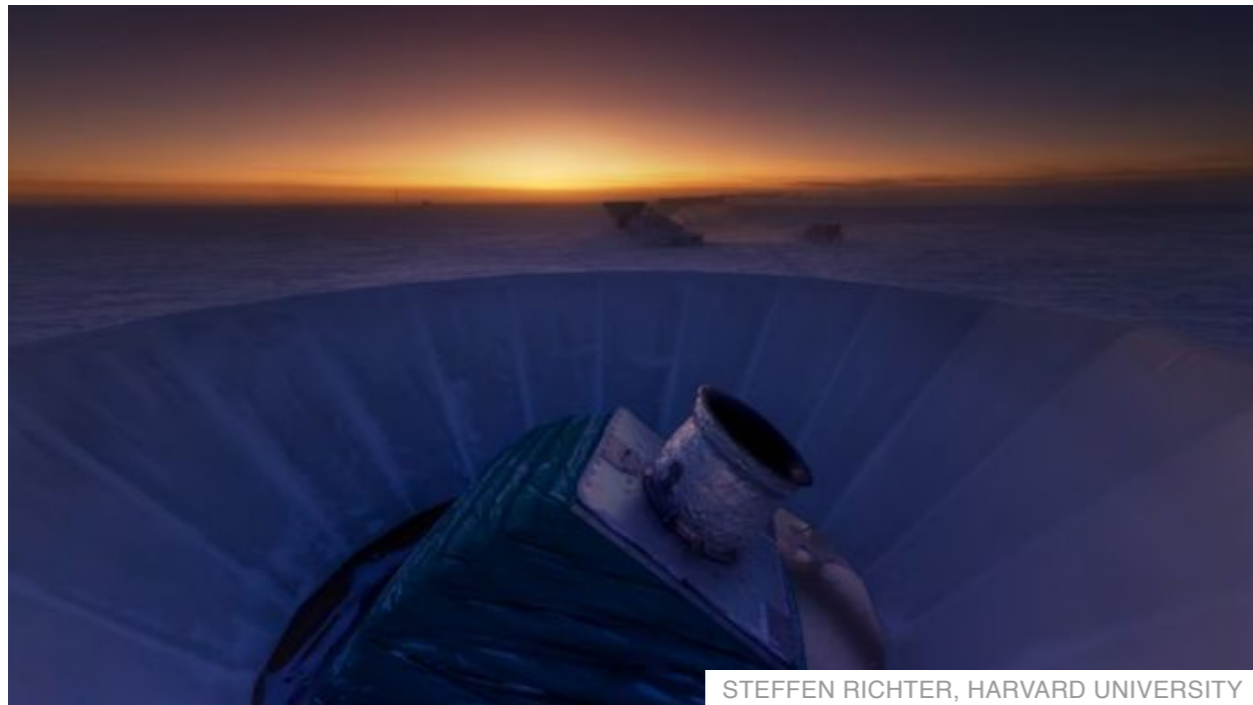


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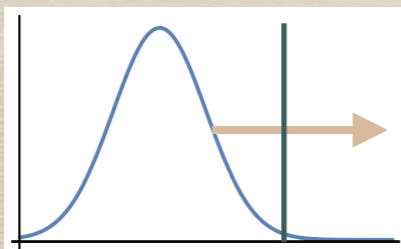
Science correspondent, BBC News

17 March 2014 | Science & Environment



STEFFEN RICHTER, HARVARD UNIVERSITY

Background from galactic dust emission underestimated



nature

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Published online 22 September 2011 | Nature |

doi:10.1038/news.2011.554

Updated online: 23 September 2011

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News

## Particles break light-speed limit

Neutrino results challenge cornerstone of modern physics.

Geoff Brumfiel



# Recent Embarrassments

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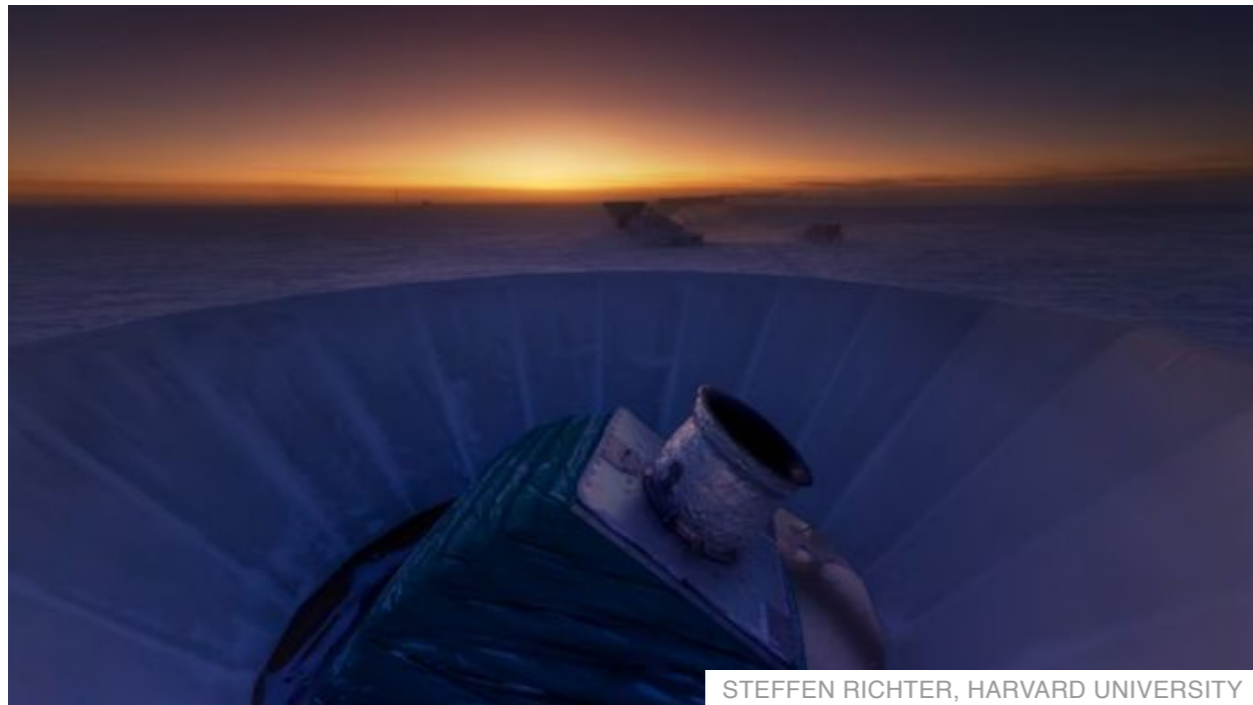


## Cosmic inflation: 'Spectacular' discovery hailed

By Jonathan Amos

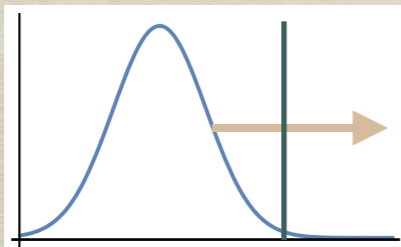
Science correspondent, BBC News

17 March 2014 | Science & Environment



STEFFEN RICHTER, HARVARD UNIVERSITY

Background from galactic dust emission underestimated



nature

International weekly journal of science

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Published online 22 September 2011 | Nature |

doi:10.1038/news.2011.554

Updated online: 23 September 2011

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## Particles break light-speed limit

Neutrino results challenge cornerstone of modern physics.

Geoff Brumfiel

A cable was not tightened



# Other Psychological Effects

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**Confirmation Bias**



# Other Psychological Effects

**Confirmation Bias**

**Texas Sharpshooter's Fallacy**

# Other Psychological Effects

**Confirmation Bias**

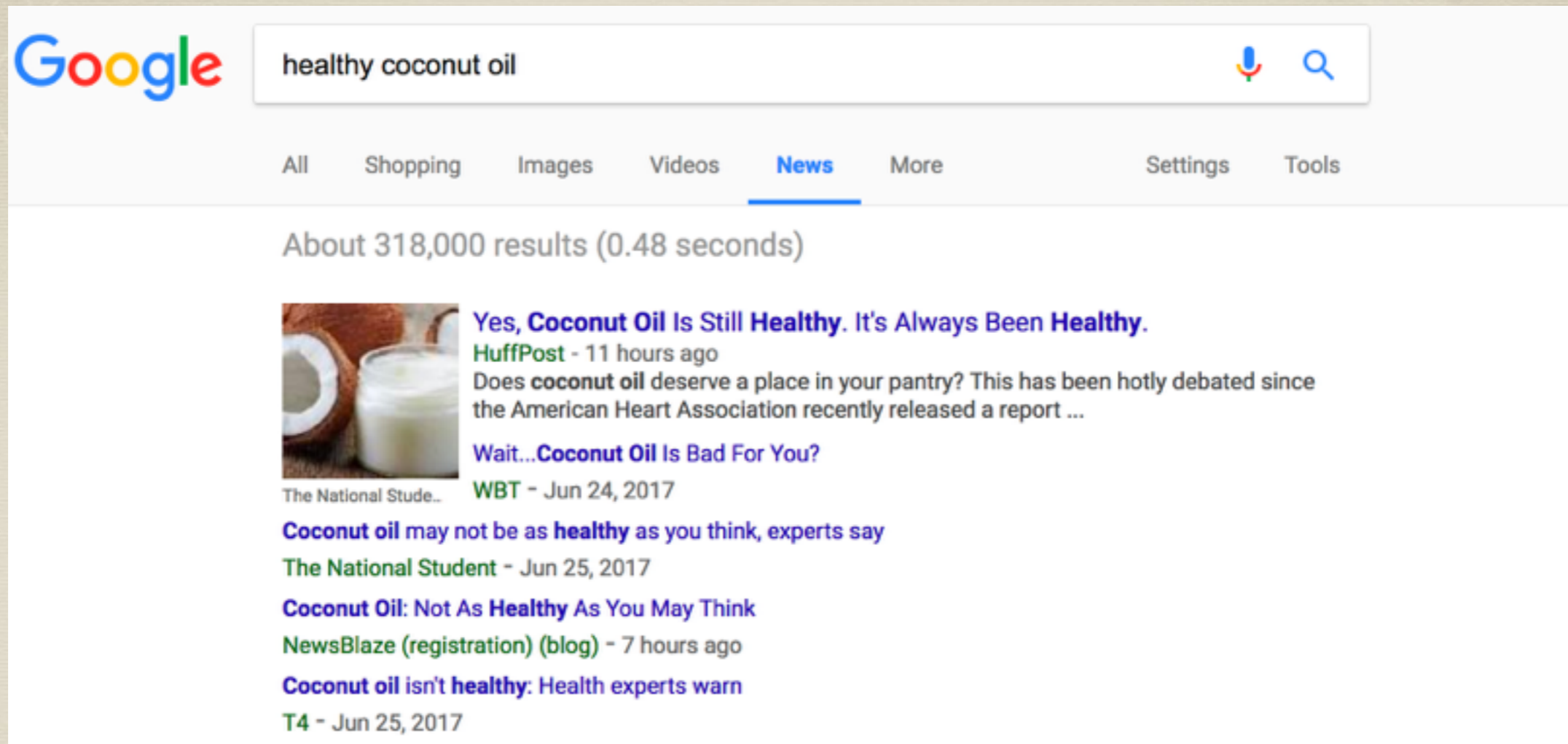
**Texas Sharpshooter's Fallacy**

For many more, see *You Are Not So Smart* Podcast



# Science Media Literacy

# Science Media Literacy




The image shows a Google search interface with the query "healthy coconut oil". The search results are filtered to "News" and show approximately 318,000 results found in 0.48 seconds. The first result is from HuffPost, titled "Yes, Coconut Oil Is Still Healthy. It's Always Been Healthy.", published 11 hours ago. The snippet asks if coconut oil deserves a place in the pantry, citing a report from the American Heart Association. Below this are several other news snippets with titles like "Wait...Coconut Oil Is Bad For You?", "Coconut oil may not be as healthy as you think, experts say", "Coconut Oil: Not As Healthy As You May Think", and "Coconut oil isn't healthy: Health experts warn".

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About 318,000 results (0.48 seconds)

 **Yes, Coconut Oil Is Still Healthy. It's Always Been Healthy.**  
HuffPost - 11 hours ago  
Does **coconut oil** deserve a place in your pantry? This has been hotly debated since the American Heart Association recently released a report ...

**Wait...Coconut Oil Is Bad For You?**  
The National Stude... WBT - Jun 24, 2017

**Coconut oil may not be as healthy as you think, experts say**  
The National Student - Jun 25, 2017

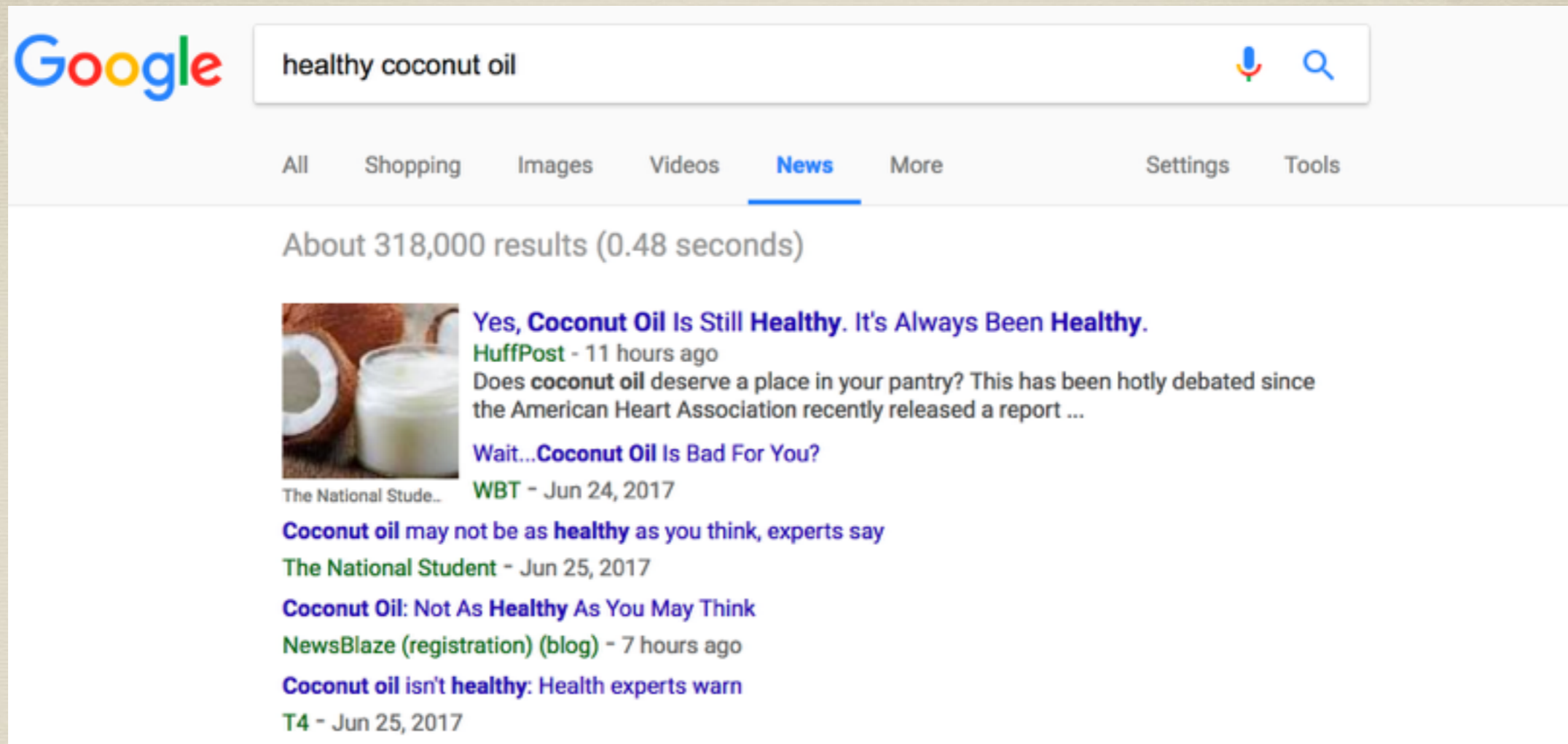
**Coconut Oil: Not As Healthy As You May Think**  
NewsBlaze (registration) (blog) - 7 hours ago

**Coconut oil isn't healthy: Health experts warn**  
T4 - Jun 25, 2017

Our students will need to process articles about scientific results every day, of varying expertise



# Science Media Literacy



The image shows a Google search interface with the query "healthy coconut oil". The search results are filtered to "News". The top result is from HuffPost, titled "Yes, Coconut Oil Is Still Healthy. It's Always Been Healthy.", published 11 hours ago. Below it is a result from The National Student, titled "Wait...Coconut Oil Is Bad For You?", dated Jun 24, 2017. Other results include "Coconut oil may not be as healthy as you think, experts say" from The National Student (Jun 25, 2017), "Coconut Oil: Not As Healthy As You May Think" from NewsBlaze (7 hours ago), and "Coconut oil isn't healthy: Health experts warn" from T4 (Jun 25, 2017). A small image of coconut oil is visible on the left side of the first result.

Our students will need to process articles about scientific results every day, of varying expertise

Everybody has to be wary of their own psychological biases, critically evaluate study/report, and remain skeptical

# Science as Evolving Story

Science can be a messy process, with lurches and starts  
before a clear understanding



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In this modern age, have to fight natural desire to get  
all of the answers now

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Unfortunately, we can't be experts on everything, so  
we have to evaluate and find trusted sources



# Conclusions

- 5 sigma discovery standard
- Look elsewhere effect
- Replication crisis and past wrong results
- Science Media Literacy and Science as an Evolving Story

Thanks for your time!