NaN

"NaN" stands for:

Not a Number

# What kinds of things give us NaN?

# Fuzzy math

```
console.log(
  0 / 0,
  Infinity / Infinity,
  0 * Infinity,
  Infinity - Infinity
);
```

```
> NaN NaN NaN NaN
```

# Complex Numbers

```
console.log(
  Math.sqrt(-1),
  Math.log(-1),
  Math.acos(2),
  Math.asin(2)
);
```

```
› NaN NaN NaN NaN
```

# Turning things into Numbers

```
console.log(
  parseInt('hello'), parseFloat('world'),
  Number(undefined), Number({}),
  +undefined, +{},
  +new Date('hello')
);
```

```
> NaN NaN NaN NaN NaN NaN NaN
```

# What is NaN? (in JavaScript)

# "Not a Number" is...

```
console.log(NaN);
```

```
> NaN
```

... a particular JavaScript value.

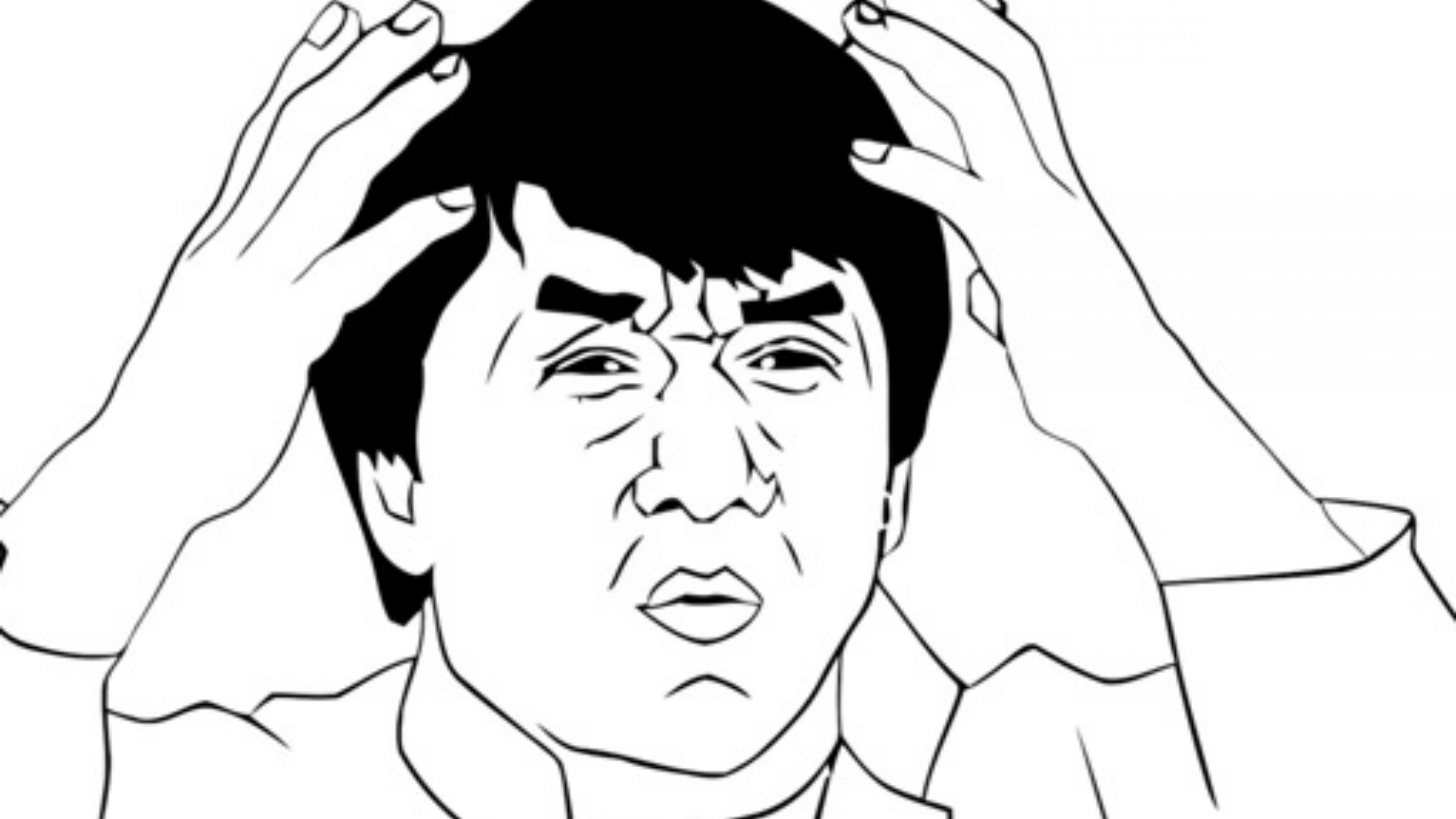
(very particular)

# "Not a Number" is...

```
console.log(typeof NaN);

> number
```

...a Number.

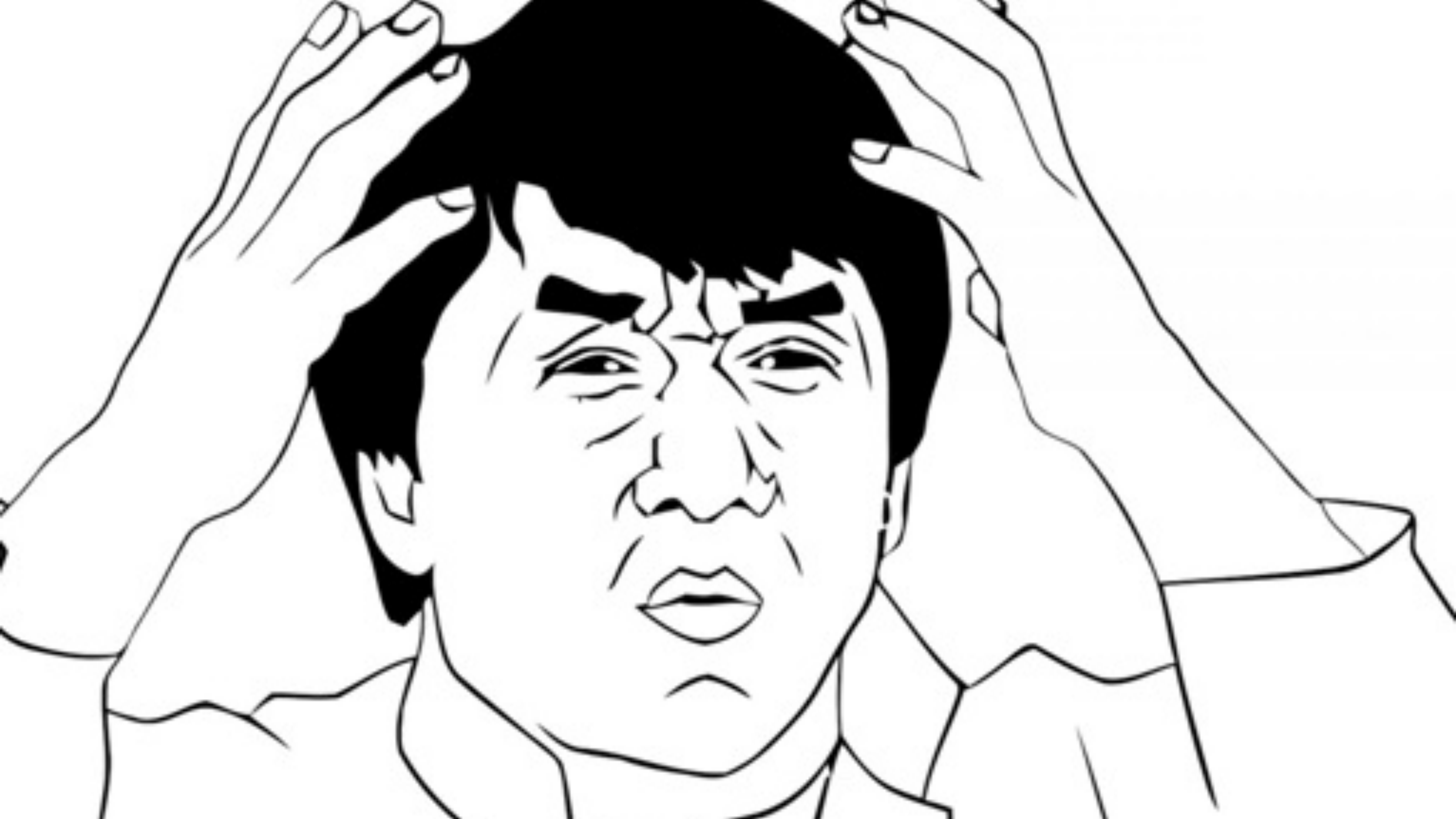


# "Not a Number" is...

```
console.log(NaN === NaN);
```

```
› false
```

...not "Not a Number".



# "Not a Number" is...

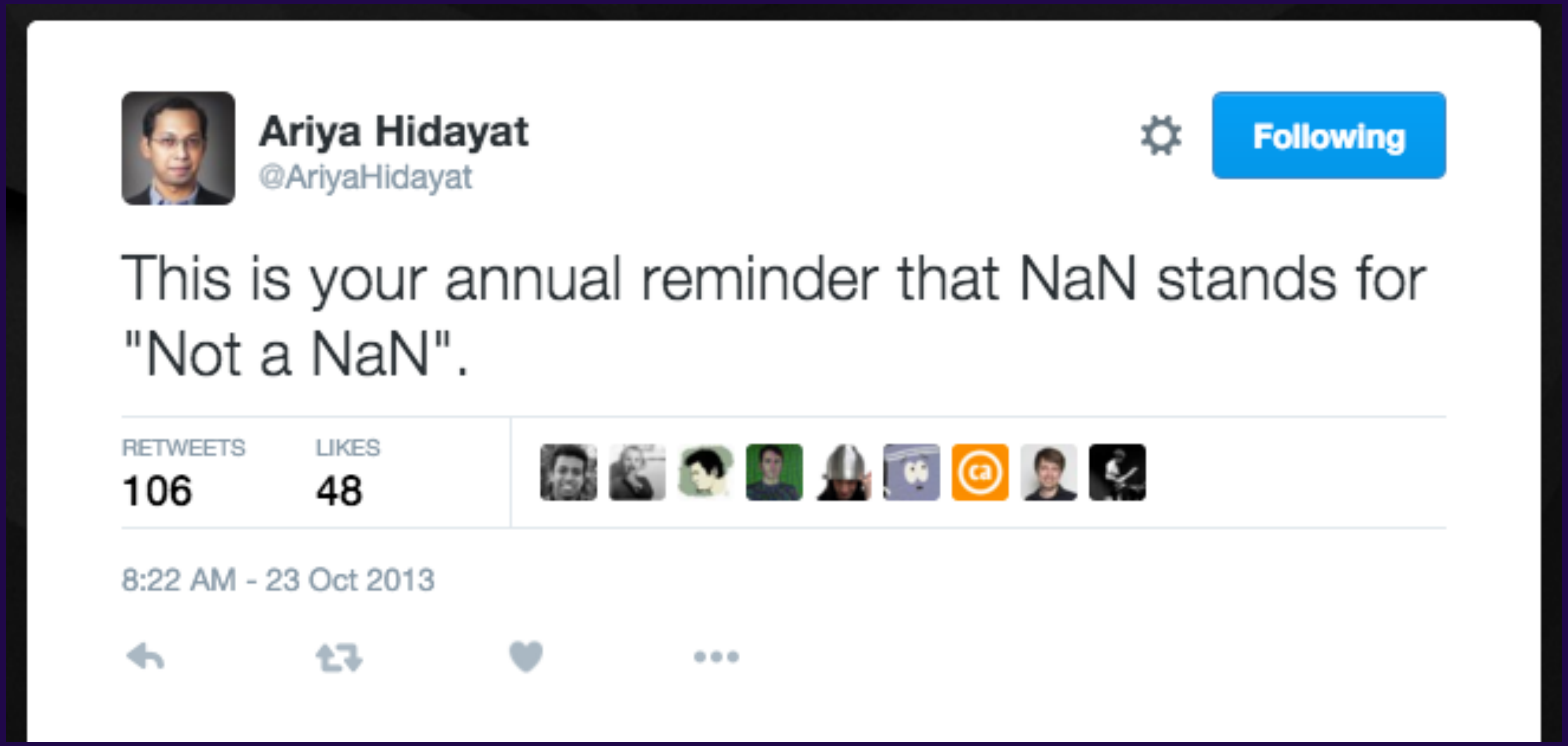
```
var assert = require('assert');
assert.equal(NaN, NaN);
```

```
› AssertionError: NaN == NaN
```

...tricky to test.

"NaN" actually stands for:

Not a NaN


Ariya Hidayat
@AriyaHidayat
Following
This is your annual reminder that NaN stands for "Not a NaN".
RETWEETS
106
LIKES
48
8:22 AM - 23 Oct 2013

So we know where NaN appears, but how do we tell if something **is** NaN?

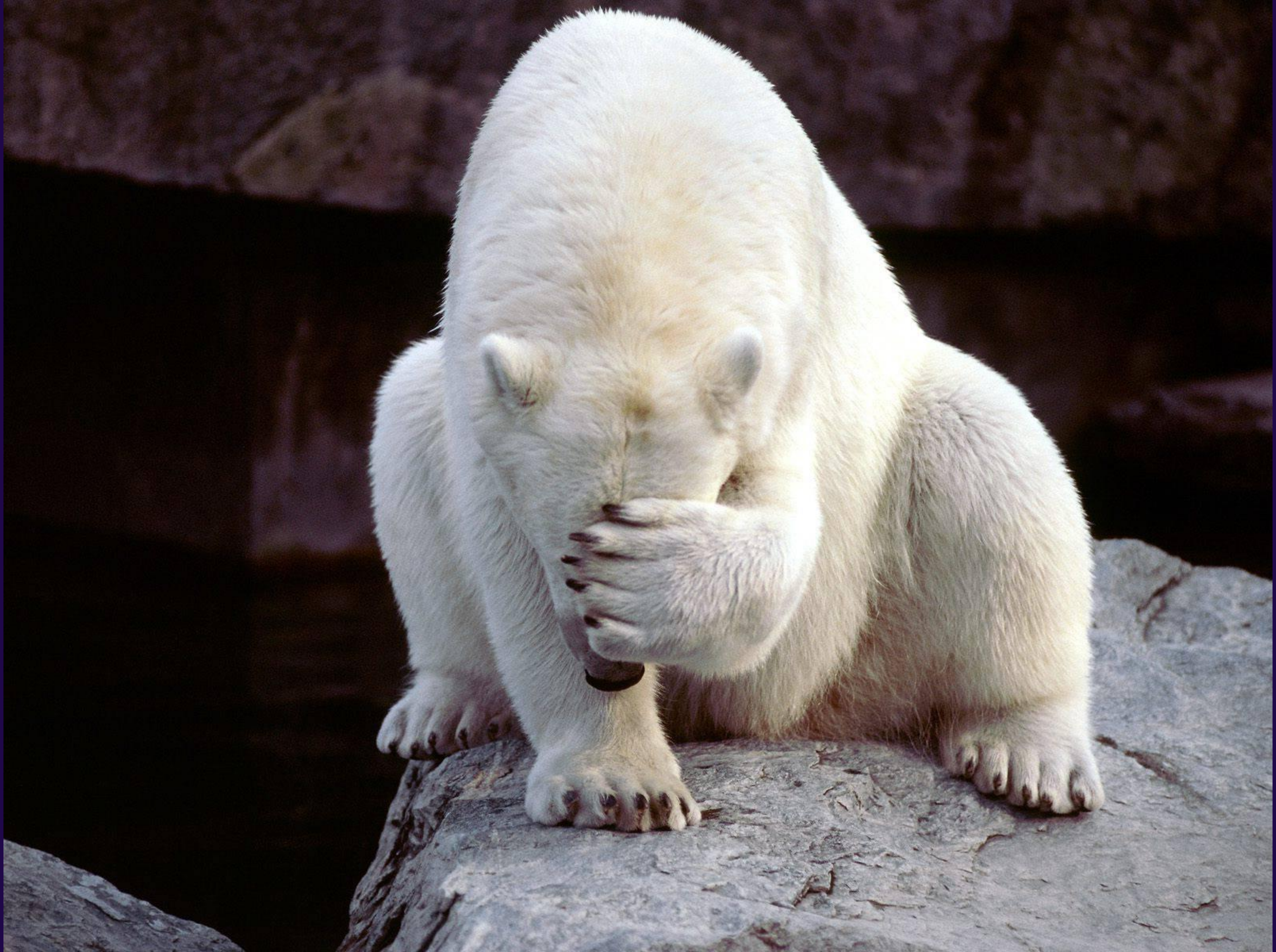
# Easy! Just use the isNaN function:

```
console.log(isNaN(NaN));
```

```
> true
```

# Or maybe not...

```
console.log(isNaN('foo'), isNaN(['bar']), isNaN({}));
› true true true
console.log(typeof 'foo', typeof ['bar'], typeof {});
› string object object
```



# So let's just make our own:

```
function myIsNaN(x) {
  return typeof x === 'number' && isNaN(x);
}

console.log([NaN, 'foo', ['bar'], {}].map(isNaN));
console.log([NaN, 'foo', ['bar'], {}].map(myIsNaN));
```

```
> true true true true
> true false false false
```

# Or we can recall "Not a NaN":

```
function myIsNaN(x) {
  return x !== x;
}

console.log([NaN, 'foo', ['bar'], {}].map(isNaN));
console.log([NaN, 'foo', ['bar'], {}].map(myIsNaN));

> true true true true
> true false false false
```

This works because NaN is the **only** value in JavaScript for which the equality operators are **non-reflexive.**

# Fortunately, ES2015 adds `Number.isNaN`:

```
console.log([NaN, 'foo', ['bar'], {}].map(isNaN));
console.log([NaN, 'foo', ['bar'], {}].map(Number.isNaN));
```

...and it does what we want:

```
› true true true true
› true false false false
```

# Or we can use `Object.is`:

```
console.log([NaN, 'foo', ['bar'], {}].map(isNaN));
console.log([NaN, 'foo', ['bar'], {}].map(n => Object.is(n, NaN)));
```

```
> true true true true
> true false false false
```

This uses the `SameValue` internal operation, which is (mostly) like how a `Set` distinguishes its elements.

# But NaN isn't just a JavaScript thing!

NaN is actually defined by the IEEE 754 floating-point standard.

If you know where NaN appears and how it behaves in one language, that carries over to most others.

Most.

Fun fact about that...

# The IEEE 754 spec defines the pow function:

```
pow(2, 3) -> 8
pow(-1, 1.5) -> NaN
pow(NaN, anything) -> NaN
pow(anything, NaN) -> NaN
```

If either input is `NaN`, or if the base is negative and the exponent is not an integer, the result is `NaN`.

# Three indeterminate forms of pow:

```
pow(0, 0) -> 1
pow(Infinity, 0) -> 1
pow(1, Infinity) -> 1
```

This behavior is inherited from C99 and POSIX 2001.

Most languages follow this.

# Here's what Python does:

```
[0 ** 0, float("inf") ** 0, 1 ** float("inf")]
```

```
› [1 1.0 1.0]
```

# And Ruby:

```
[0 ** 0, Float::INFINITY ** 0, 1 ** Float::INFINITY]
```

```
› [1 1.0 1.0]
```

# And Lua:

```
print(math.pow(0, 0), math.pow(math.huge, 0), math.pow(1, math.huge))
```

```
> 1 1 1
```

# But JavaScript?

```
Math.pow(0, 0);
```

```
Math.pow(0, 0);

> 1
```

```
Math.pow(0, 0);

> 1

Math.pow(Infinity, 0);
```

```
Math.pow(0, 0);

> 1

Math.pow(Infinity, 0);

> 1
```

```
Math.pow(0, 0);

> 1

Math.pow(Infinity, 0);

> 1

Math.pow(1, Infinity);
```

```
Math.pow(0, 0);

> 1

Math.pow(Infinity, 0);

> 1

Math.pow(1, Infinity);

> NaN
```

# Why?

### 15.8.2.13 pow (x, y)

Returns an implementation-dependent approximati

- If $y$ is NaN, the result is NaN.
- If $y$ is +0, the result is 1, even if $x$ is NaN.
- If $y$ is –0, the result is 1, even if $x$ is NaN.
- If $x$ is NaN and $y$ is nonzero, the result is NaN.
- If abs($x$)>1 and $y$ is $+\infty$, the result is $+\infty$.
- If abs($x$)>1 and $y$ is $-\infty$, the result is +0.
- If abs($x$)==1 and $y$ is $+\infty$, the result is NaN.
- If abs($x$)==1 and $y$ is $-\infty$, the result is NaN.

## 12.7.3.4 Applying the ** Operator

- If abs(*base*) is 1 and *exponent* is +∞, the result is **NaN**.
- If abs(*base*) is 1 and *exponent* is -∞, the result is **NaN**.

- ES1 specifies pow: 1997
- C99 specifies pow: 1999
- POSIX specifies pow: 2001
- IEEE 754 inherits pow: 2008

NOTE The result of *base* ** *exponent* when *base* is **1** or **-1** and *exponent* is **+Infinity** or **-Infinity** differs from IEEE 754-2008. The first edition of ECMAScript specified a result of **NaN** for this operation, whereas later versions of IEEE 754-2008 specified **1**. The historical ECMAScript behaviour is preserved for compatibility reasons.

So just like every other question about JavaScript, the answer is...

# Backwards compatibility

So anyway, what does IEEE 754 say about how we represent NaN?

# Bit representation of a float32 value:

`0 10000000 01000000000000000000000`

- 1-bit sign
- 8-bit exponent, offset by `127`
- 23-bit significand (with implicit leading 24th bit)
- `(-1) ^ s * 2 ^ (exp - 127) * 1.significand`

# Example float32 value:

```
0 10000000 01000000000000000000000

→ (-1) ^ 0 = 1

→ 2 ^ (10000000b - 127) = 2

→ 1.01b = 1.25

→ 1 * 2 * 1.25 = 2.5
```

# Bit representations of special values:

```
0 11111111 00000000000000000000000 -> Infinity
1 11111111 00000000000000000000000 -> -Infinity
```

Infinity values have a maximized exponent and a zero significand.

# Bit representations of special values:

```
0 11111111 10000000000000000000000 -> NaN
```

NaN values have a maximized exponent and a nonzero significand.

# So these are also all NaN:

```
1 11111111 10000000000000000000000 -> NaN (quiet, negative)
0 11111111 10000000000000000000001 -> NaN (quiet, but different)
0 11111111 00000000000000000000001 -> NaN (signaling)
0 11111111 00000000000000000000010 -> NaN (signaling, but different)
0 11111111 00000000000000000000011 -> NaN (we can start counting!)
```

# So these are also all NaN:

```
1 11111111 10000000000000000000000 -> NaN (quiet, negative)
0 11111111 10000000000000000000001 -> NaN (quiet, but different)
0 11111111 00000000000000000000001 -> NaN (signaling)
0 11111111 00000000000000000000010 -> NaN (signaling, but different)
0 11111111 00000000000000000000011 -> NaN (we can start counting!)
```

## How many NaNs are there, really?

$2^{24} - 2 = 16,777,214$

And that's just with a float32!

What about a double64?

$2^{52} - 2 =$

4,503,599,627,370,494

That's 4.5 * 10^15, or 4.5 quadrillion.

---

4.5 petabytes is about 10,000 years worth of music.

If there are so many different possible NaNs, then it only seems reasonable...

...that one random NaN is unlikely to be the same as another random NaN!

# Thus, NaN !== NaN[1].

[1] With probability 1/4,503,599,627,370,494.

# Some Related Links

- http://ariya.ofilabs.com/2014/05/the-curious-case-of-javascript-nan.html
- http://www.2ality.com/2012/02/nan-infinity.html
- https://en.wikipedia.org/wiki/NaN
- https://tc39.github.io/ecma262/#sec-applying-the-exp-operator

# Who are you and where can I find the slides?

- I'm Lewis J Ellis: @lewisjellis on Twitter and GitHub
- My website is LewisJEllis.com.
- Slides available at GitHub.com/LewisJEllis/nantalk