

# The Fermi Paradox

“Where is everybody?” Enrico Fermi

April 18, 2020

Matthew S. Williams, *Figuring Out Whether Aliens Exist: Possible Resolutions to the Fermi Paradox*, May 19, 2019 [Possible resolutions to the Fermi Paradox](#)

Tim Urban, *The Fermi Paradox*, May 21, 2014. [The Fermi Paradox](#)

## The Kardashev Scale:

In 1964, Soviet astronomer and SETI researcher Nikolai Kardashev proposed a classification method for grouping species based on their level of technological development. The resulting scale had three levels (or types) which classified species based on the amount of energy they could harness.

By definition, **Type I civilizations** (aka. "planetary civilizations") are those that have developed the means to harness and store all of the energy of their home planet. According to Kardashev, this would amount to the consumption of  $4 \times 10^{19} \frac{erg}{sec}$  which would likely be in the forms of fusion power, antimatter, and renewable energy on a global scale.

Next up are **Type II civilizations** ("stellar civilizations"), which evolved to the point where they could harvest all the energy emitted by their star - which Kardashev speculated would likely involve a structure like a Dyson Sphere. In this case, this would work out to a consumption of  $4 \times 10^{33} \frac{erg}{sec}$ .

**Type III civilizations** ("galactic civilizations") are those that would be able to harness the energy of an entire galaxy, which would work out to energy consumption on the order of  $4 \times 10^{44} \frac{erg}{sec}$ .

Based on the fact that the Universe has been around for 13.8 billion years, and the fact that our Solar System has only existed for the last 4.6 billion years of that, it would seem likely that at least a few civilizations would have been able to achieve a Type III level of development. Even with our modest means, it would be very difficult for humans to miss the signs of such a civilization.

So again, we are forced to ask why we have found no signs of intelligent life in the cosmos. How it is that the odds of intelligent life seems so likely, but the evidence is so lacking? Here's where things get particularly interesting, frightening, and more than a little mind-blowing.

## An improved scale of energy usage

Let's fix up the Kardashev scale a bit. Rather than simply running I, II, III, let's build a scale from 0 to 10. Let 0 represent the minimum rate of energy usage by a lone human, about 0.029 W (according to Limit of the human body) and let 10 be the approximate energy production of the visible universe, roughly the solar output times  $10^{11}$  stars in a galaxy times  $2 \times 10^{11}$  galaxies. Then we end up with the following formula relating the Civilization Type,  $T$ , to the energy usage in Watts,  $W$ :

$$-3.54 + 11.78144 \times T = \ln(W)$$

This gives the following table of types and energies:

Type:	ln(W)	Watts	
0.00	-3.54E+00	2.90E-02	Minimum human usage
0.25	-5.95E-01	5.52E-01	
0.50	2.35E+00	1.05E+01	
0.75	5.30E+00	2.00E+02	
1.00	8.24E+00	3.80E+03	
1.25	1.12E+01	7.22E+04	
1.50	1.41E+01	1.37E+06	
1.75	1.71E+01	2.61E+07	
2.00	2.00E+01	4.96E+08	
2.25	2.30E+01	9.44E+09	
2.50	2.59E+01	1.80E+11	
2.75	2.89E+01	3.41E+12	
3.00	3.18E+01	6.49E+13	Current world
3.25	3.47E+01	1.23E+15	
3.50	3.77E+01	2.35E+16	
3.75	4.06E+01	4.47E+17	
4.00	4.36E+01	8.49E+18	
4.25	4.65E+01	1.62E+20	
4.50	4.95E+01	3.07E+21	
4.75	5.24E+01	5.84E+22	
5.00	5.54E+01	1.11E+24	
5.25	5.83E+01	2.11E+25	
5.50	6.13E+01	4.02E+26	Star
5.75	6.42E+01	7.64E+27	
6.00	6.71E+01	1.45E+29	
6.25	7.01E+01	2.76E+30	
6.50	7.30E+01	5.26E+31	
6.75	7.60E+01	9.99E+32	
7.00	7.89E+01	1.90E+34	
7.25	8.19E+01	3.61E+35	
7.50	8.48E+01	6.87E+36	Galaxy
7.75	8.78E+01	1.31E+38	
8.00	9.07E+01	2.49E+39	
8.25	9.37E+01	4.73E+40	
8.50	9.66E+01	8.99E+41	
8.75	9.95E+01	1.71E+43	
9.00	1.02E+02	3.25E+44	
9.25	1.05E+02	6.18E+45	
9.50	1.08E+02	1.18E+47	
9.75	1.11E+02	2.24E+48	
10.00	1.14E+02	4.25E+49	Universe