

# Announcements

- Exploration paper 4 due Mar 29
  - Topic: Extraterrestrial Intelligence; see Canvas for details
- Quiz 5 coming up next Monday, Apr 1 (not a joke!)
  - Topic: chapter 5 & this week's lectures



For exploration paper 4: you can choose any article from the August 2022 special edition of Scientific American to explore in more detail; otherwise, you can use the topics in the book/on Canvas



Contact

Directed:  
Robert Zemeckis

Warner Brothers (1997)

# The Drake Equation

$$N = R^\star \times f_p \times n_E \times f_l \times f_i \times f_c \times L$$

$R^\star$  : average star formation rate in the Galaxy (**measured**  $\sim 3 M_\odot/\text{yr} \rightarrow 6\star/\text{yr}$  )

$f_p$  : fraction of stars with planets (**measured**  $\sim 1$ )

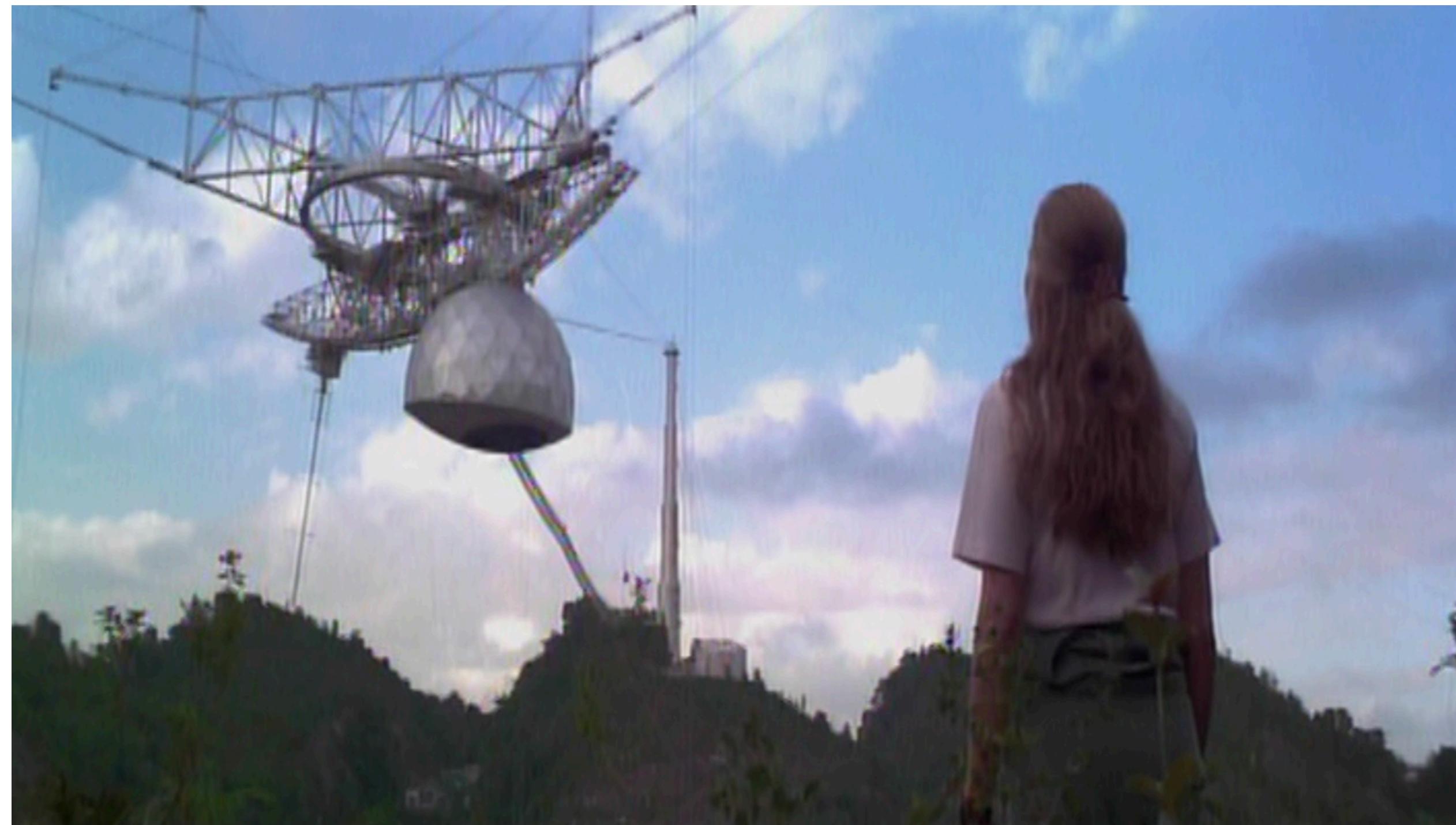
$n_E$  : number of Earth-like planets per star (assumed  $> 1$ )

$f_l$  : fraction of Earth-like planets with life (assumed  $\sim 1$ )

$f_i$  : fraction of life sustaining planets with intelligent life (assumed  $\sim 1$ )

$f_c$  : fraction of intelligent civilizations capable of communication (assumed  $\sim 1$ )

$L$  : average lifetime of radio-communicating civilization (?? Earth:  $\sim 100$  years)



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# Arecibo observatory - Puerto Rico



305 m across &  
completed in 1963

Largest radio dish  
on Earth until FAST  
dish was built by  
China in 2016  
(500 m)

# Arecibo observatory - Puerto Rico



305 m across &  
completed in 1963

Collapsed  
December 1, 2020

Still out of  
commission today



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There are 400 billion stars out there, just in our Galaxy alone

If only one out of a million of those had planets ...

And only one out of a million of those had life ...

And one out of a million of those had intelligent life ...

There would be *literally* millions of civilizations in the Galaxy

There are 400 billion stars out there, just in our Galaxy alone

If only one out of a million of those had planets ...  $4 \times 10^{11}/10^6 = 4 \times 10^5$

And only one out of a million of those had life ...  $4 \times 10^5/10^6 = 0.4$

And one out of a million of those had intelligent life ...  $0.4/10^6 = 4 \times 10^{-7}$

There would be **basically zero** of civilizations in the Galaxy

# What could communication look like with ET?

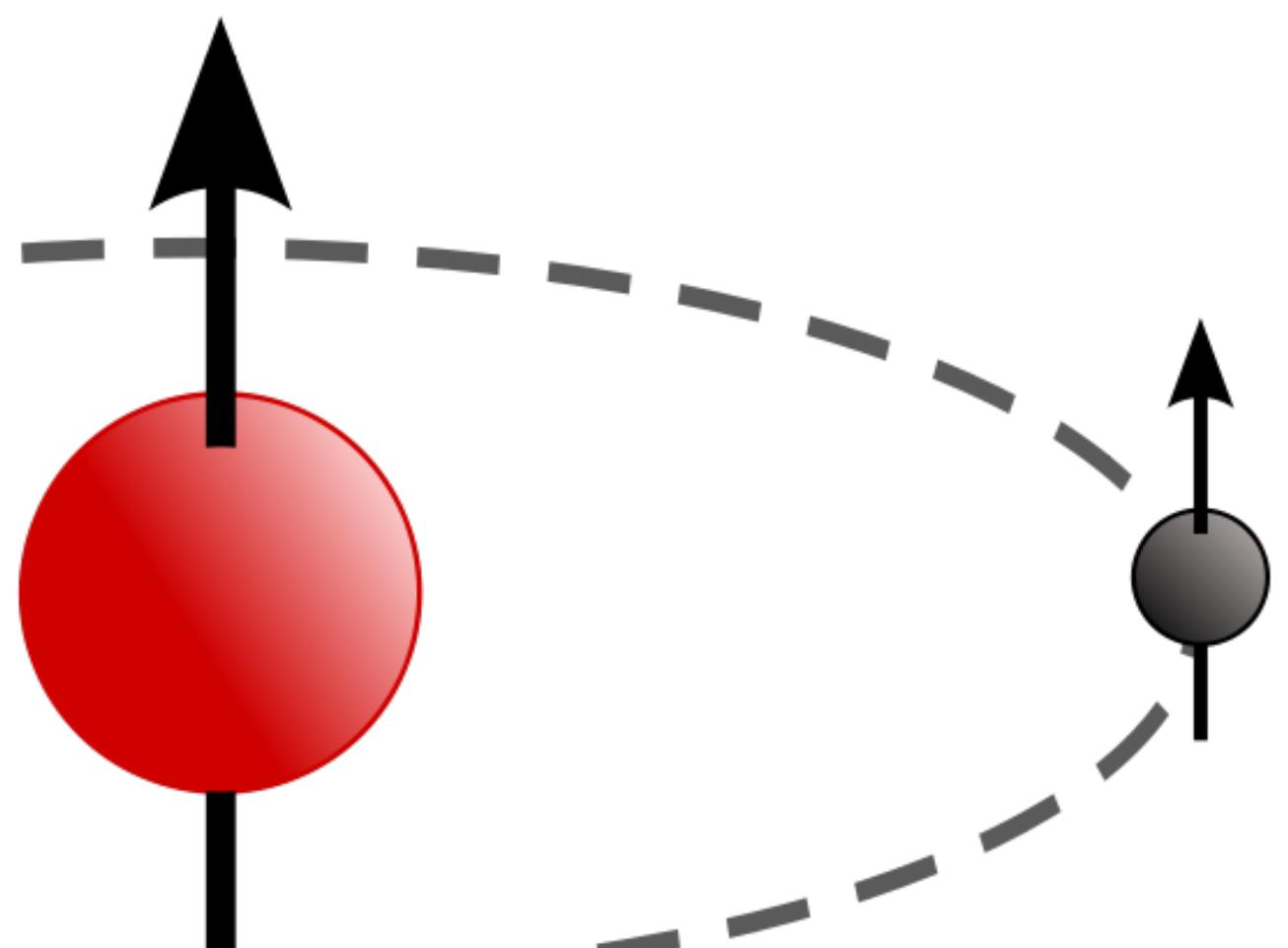


Contact

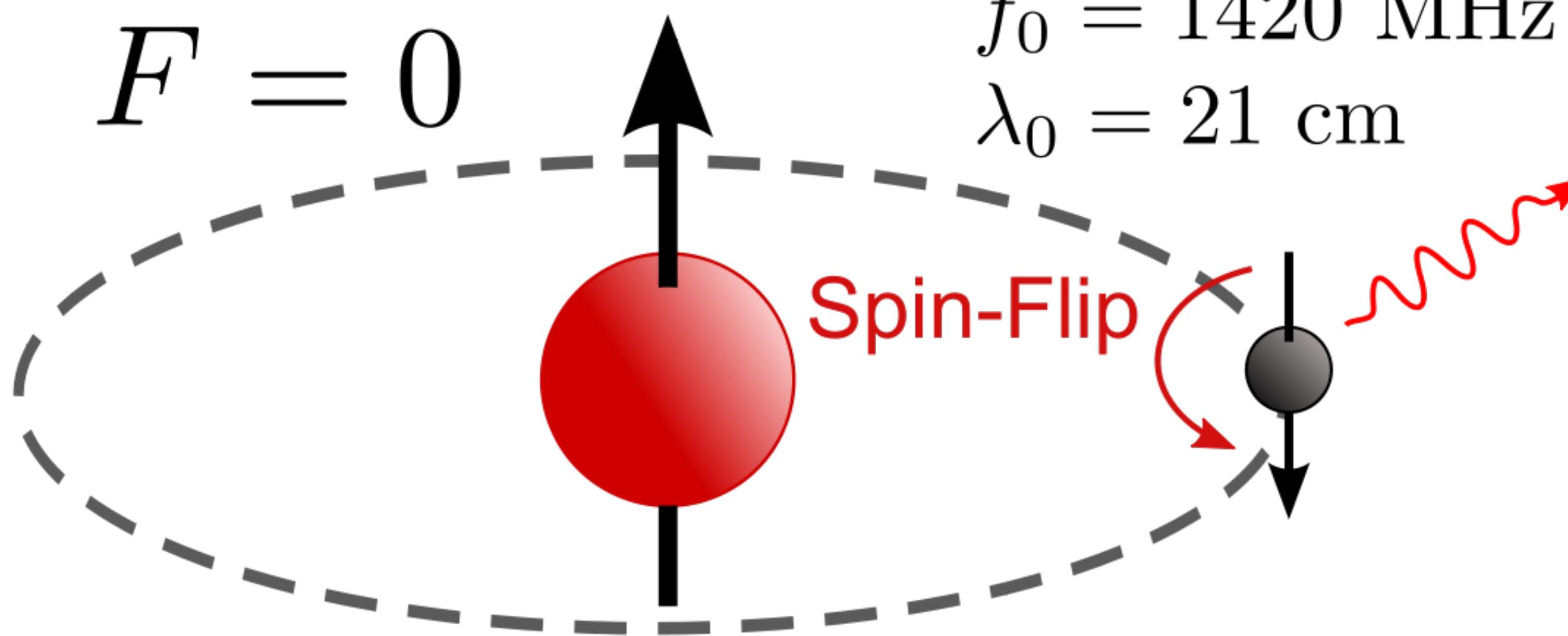
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Robert Zemeckis

Warner Brothers (1997)

$$F = 1$$



$$F = 0$$



“Hydrogen times  $\pi$ ”

Hydrogen:

1 proton + 1 electron

Electrons have spin  
energies that differ if  
they are pointed  
up or down

$$f_0 \times \pi = 1420 \text{ MHz} \times \pi = 4460 \text{ MHz}$$

# What could communication look like with ET?



Enterprise  
“Broken Bow”

Written:  
Ricke Berman &  
Brannon Brags

Paramount (2001)

# What could communication look like with ET?



Even with a trained linguist,  
tools will required  
development and testing.

Today machine learning is  
used to create human  
language translations;  
requires large training sets  
created by experts

# What could communication look like with ET?



Arrival

Directed:  
Denis Villeneuve

Paramount (2016)

# What could communication look like with ET?



Heptopods:

Human description of aliens  
that visited Earth

Nonverbal

Communication:

Why did they choose to park  
there?

*Non-correlated communication between writing and sound*

Next week begins:

What does it mean to be human?