Write, Don't Radiate

Chris Rose
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Breakthrough Discuss
Stanford
April 15, 2016

Phil Kicked SETI Off

SEARCHING FOR INTERSTELLAR COMMUNICATIONS

By GIUSEPPE COCCONI* and PHILIP MORRISON†
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NO theories yet exist which enable a reliable estimate of the probabilities of (1) planet formation ; (2) origin of life ; (3) evolution of societies possessing advanced scientific capabilities. In the absence of such theories, our environment suggests that stars of the main sequence with a lifetime of many billions of years can possess planets, that of a small set of such planets two (Earth and very probably Mars) support life, that life on one such planet includes a society recently capable of considerable scientific investigation. The lifetime of such societies is not known ; but it seems unwarranted to deny that among such societies some might maintain themselves for times very long compared to the time of human history, perhaps for times comparable with geological time. It follows, then, that near some star rather like the Sun there are civilizations with scientific interests and with technical possibilities much greater than those now available to us.

* Now on leave at CERN, Geneva.
† Now on leave at the Imperial College of Science and Technology, London, S.W.7.

To the beings of such a society, our Sun must appear as a likely site for the evolution of a new society. It is highly probable that for a long time they will have been expecting the development of science near the Sun. We shall assume that long ago they established a channel of communication that would one day become known to us, and that they look forward patiently to the answering signals from the Sun which would make known to them that a new society has entered the community of intelligence. What sort of a channel would it be ?

The Optimum Channel

Interstellar communication across the galactic plasma without dispersion in direction and flight-time is practical, so far as we know, only with electromagnetic waves.

Since the object of those who operate the source is to find a newly evolved society, we may presume that the channel used will be one that places a minimum burden of frequency and angular discrimi-

Nature 184, pp.844–846, September 19, 1959, Cocconi & Morrison

Write or Radiate?

Nature 431, pp.47–49, September 2, 2004, Rose & Wright

SESSION TITLE: Optical SETI and Detectability of Directed Energy Systems

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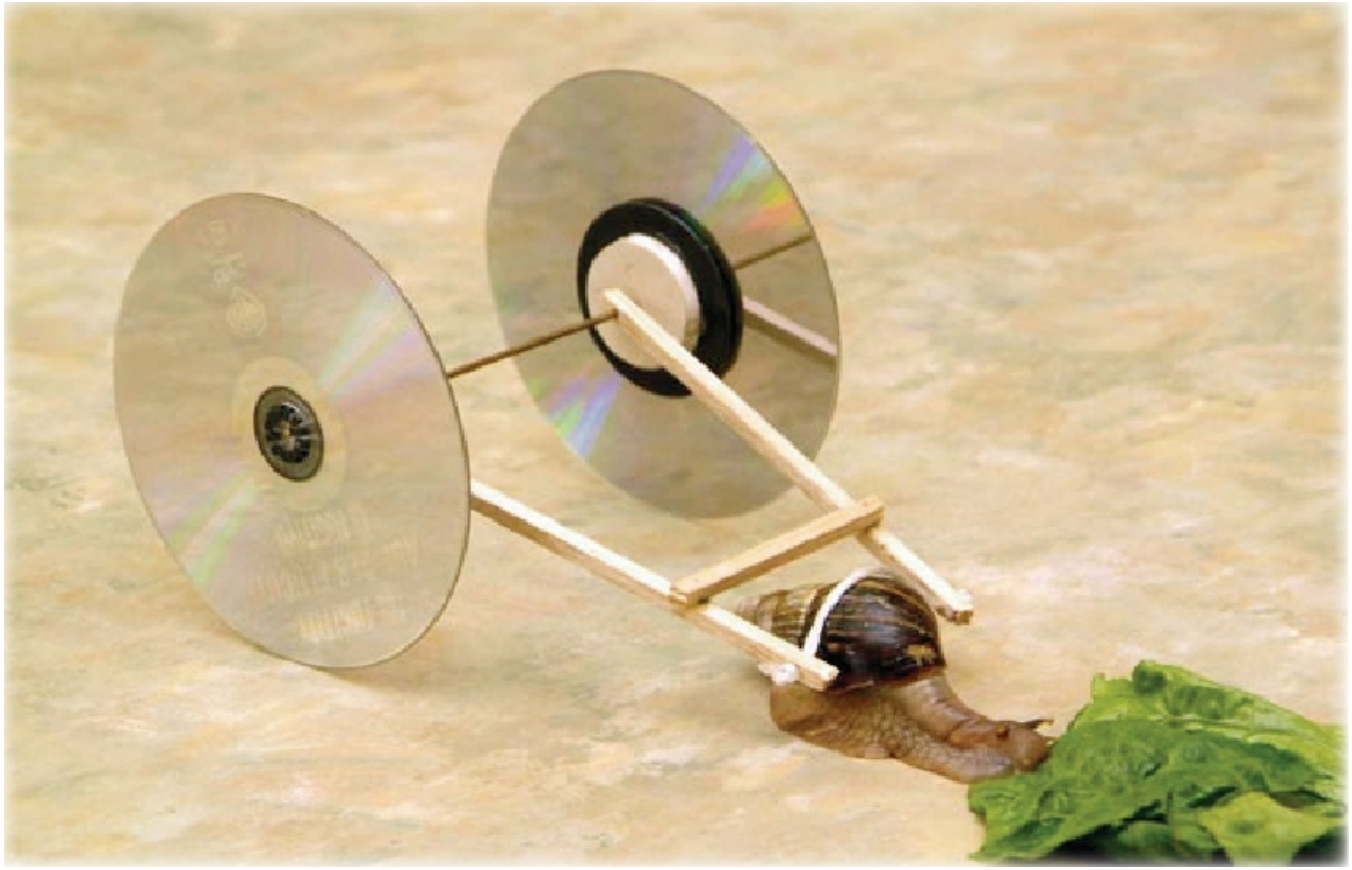
Me right now

Something Communication Theorists Know

A truck filled with storage media, driven across town, is a very reliable high bit rate channel.

– Communication Theory Zeitgeist

Sluggish Data vs. ADSL



Annals of Improbable Research 11(4), 2005

Cute, But ...

Fundamental Question

Info delivery cost via Photons
vs.
Info delivery cost via Package

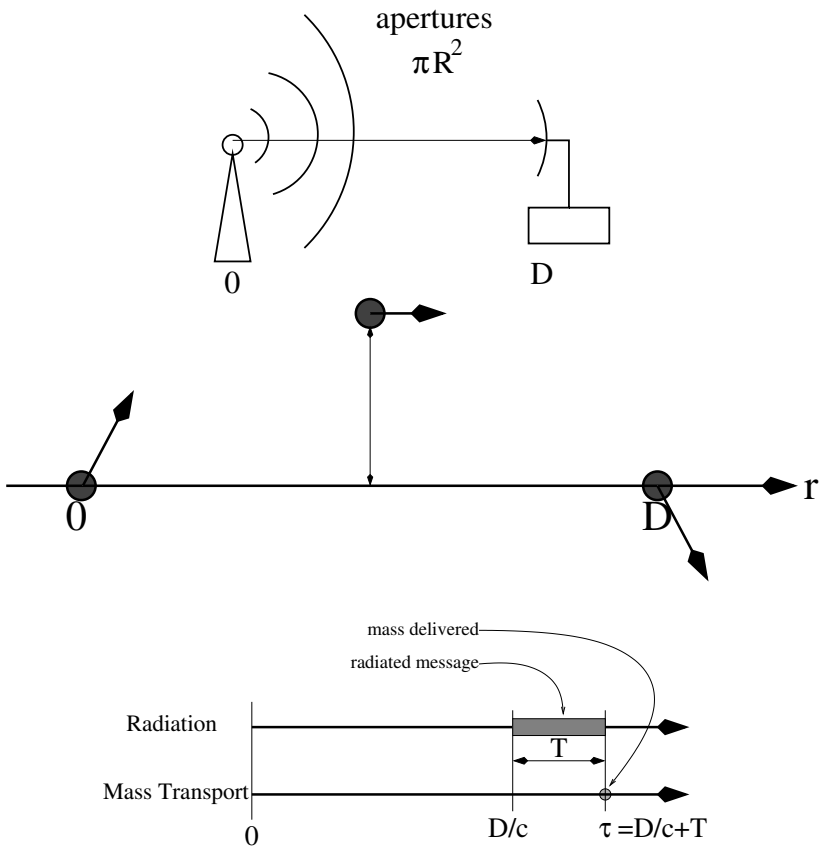
Cute, But ...

Fundamental Question

Info delivery cost via Photons
vs.
Info delivery cost via Package

Info $\Leftrightarrow$ Bits
Cost $\Leftrightarrow$ Energy

A Little Analytic Rigor



Two New Units!

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$\tilde{\rho} \equiv$ Mass Info Density

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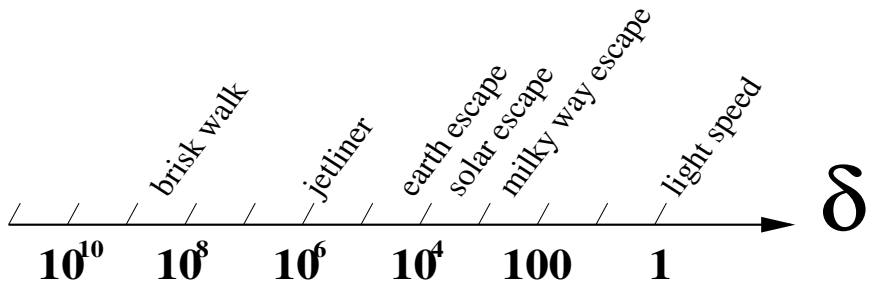
$\tilde{\rho} \equiv$ Mass Info Density

$\delta = \frac{c}{v} \equiv$ Transport Latency

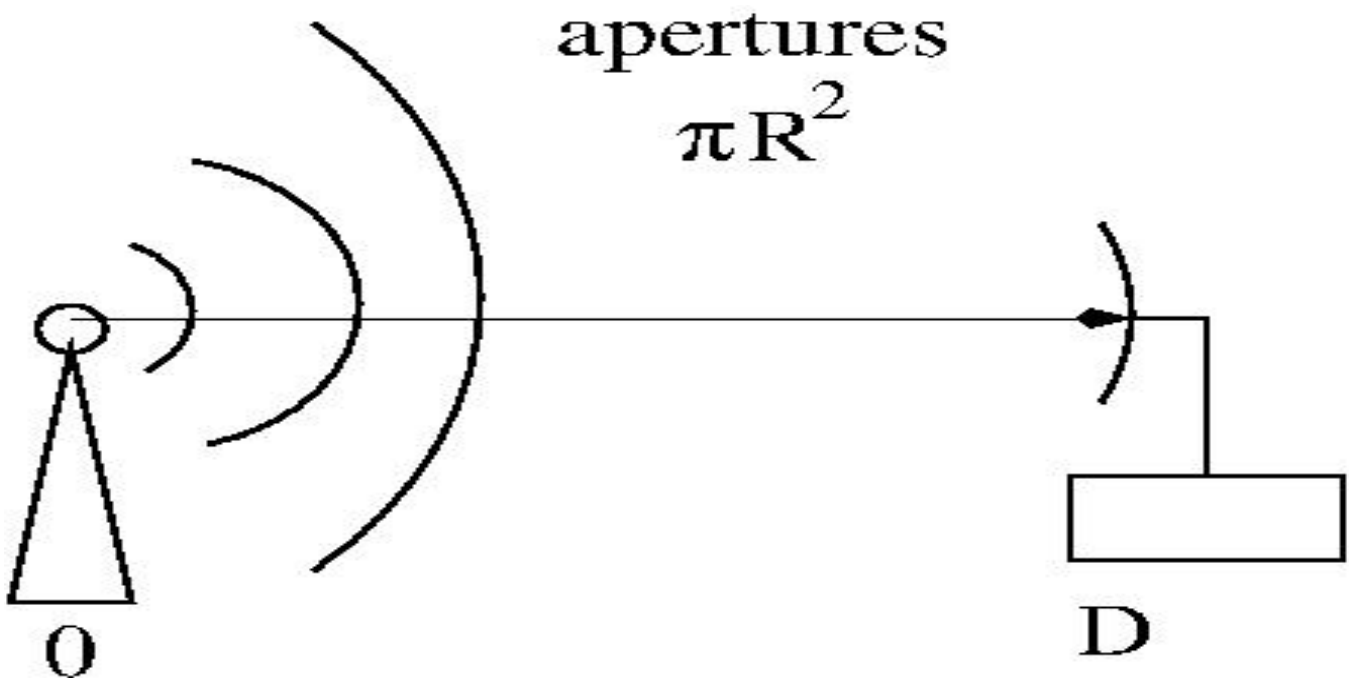


Inscribed Matter Energy Requirements

$$m = \tilde{\rho} B$$

$$\mathcal{E}_w \geq \frac{1}{2} m \bar{v}^2 = \frac{1}{2} \frac{B}{\tilde{\rho}} \left(\frac{c}{\delta} \right)^2$$

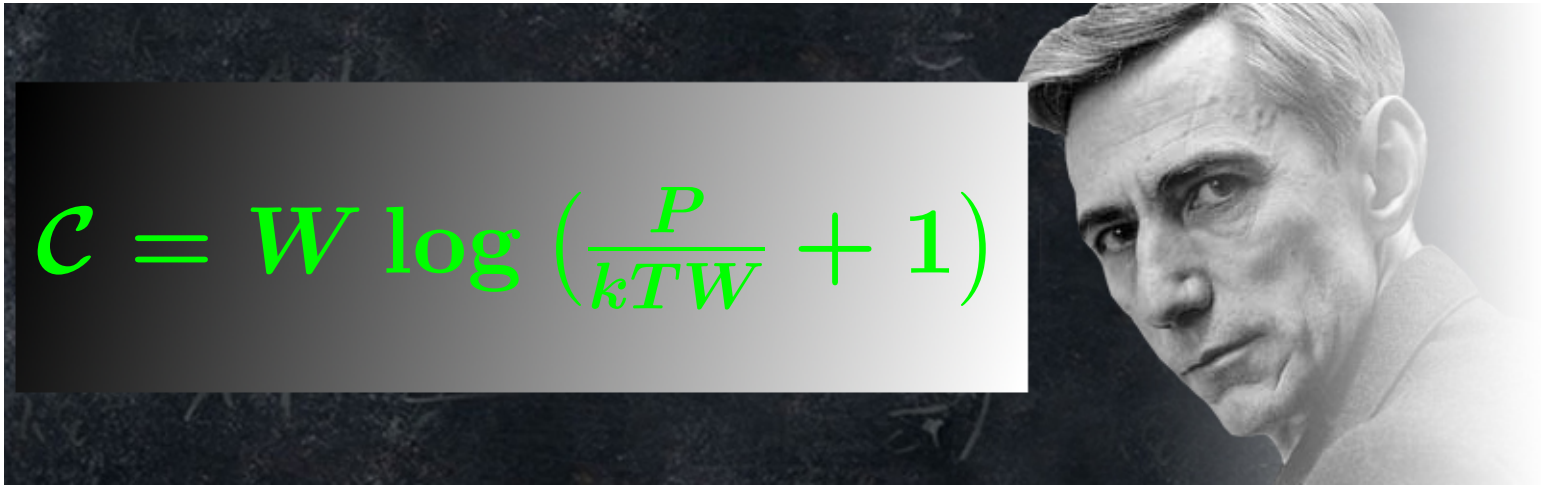
Radiation and Energy Capture



Omni: $P\frac{R^2}{4D^2}$ Directional: $P\frac{R^2G}{4D^2}$

Drum Roll Please ...

Drum Roll Please ...



ALL HAIL SHANNON!

Radiation to Transport Energy Ratio

$$\Omega \equiv \frac{E_r}{E_w}$$

Radiation to Transport Energy Ratio

$$\boxed{\Omega \equiv \frac{E_r}{E_w}}$$

Receiver Noise $\equiv N_0$ Joules/Hz
Mass Information Density $\equiv \tilde{\rho}$ bits/kg
Velocity Ratio $\equiv \delta = \frac{c}{v}$
Normalized Aperture $\equiv \mathcal{A} = \frac{2R}{\lambda}$
Normalized Distance $\equiv \mathcal{D} = \frac{D}{2R}$

$$\Rightarrow \boxed{\Omega \geq \left[\frac{\tilde{\rho} N_0}{c^2}\right] \left[\frac{8}{\pi^2}\left(\frac{\mathcal{D}}{\mathcal{A}}\right)^2\right] (2\ln 2)\delta^2} \Leftarrow$$

Equal Receiver/Transmitter Apertures

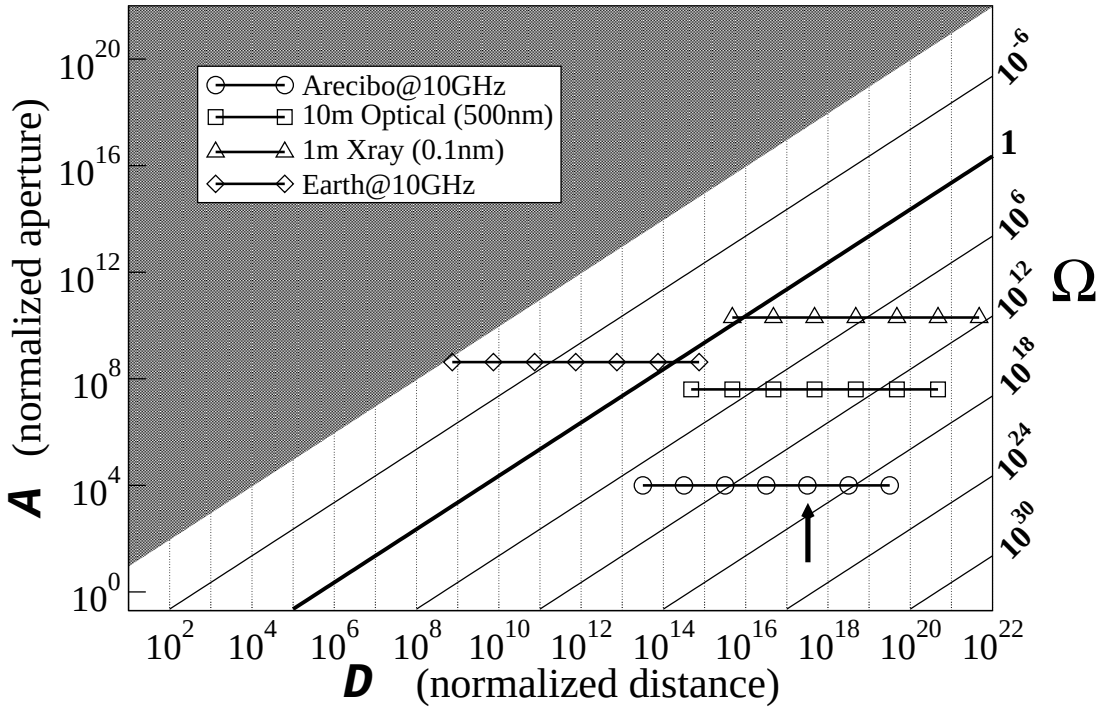
Empirical Mass Information Densities

- **20 lb paper** @ 1000dpi: 2×10^{10} bits/kg
- **DVD**: 3×10^{12} bits/kg
- **Magnetic Storage** with FeO_2: 2×10^{17} bits/kg
- **Optical Lithography** with SiO_2: 3.85×10^{18} bits/kg
- **E-beam Lithography** with SiO_2: 1.54×10^{21} bits/kg
- **STM** with Xe on Ni: 1.74×10^{22} bits/kg
- **RNA**: 3.6×10^{24} bits/kg
- **Li + Be**: 7.5×10^{25} bits/kg

Radiation
vs.
Inscribed Matter

General Interstellar

($\tilde{\rho} = 10^{22}$, $\delta = 10^{3}$, Temperature 3°K)



10k Light Years

Arecibo $\Leftrightarrow$ Arecibo

$\tilde{\rho} = 10^{22}$, $\delta = 10^{3}$, Temperature $3°$K

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Radiation
Matter

10k Light Years

Arecibo $\Leftrightarrow$ Arecibo

$\tilde{\rho} = 10^{22}$, $\delta = 10^{3}$, Temperature $3°$K

Radiation
Matter

24 Megaton blast
Shelve a 5 lb sugar bag

hey, Hey HEY!!!!! What About ... ?

hey, Hey HEY!!!!! What About ... ?

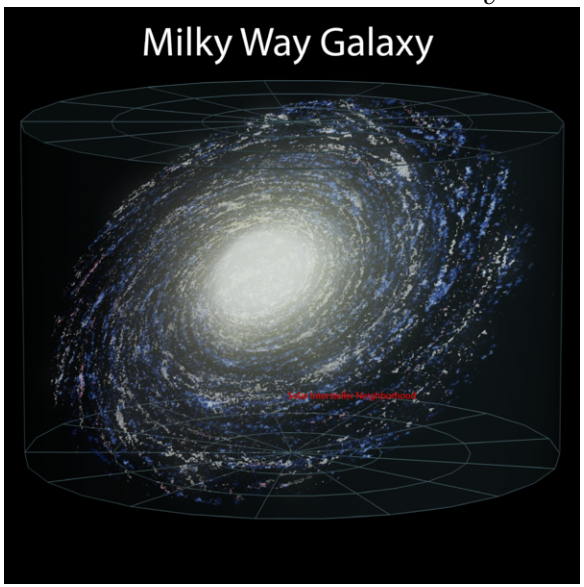
- **Radiation Penalty**
  - Impermanence and Repetition
- **Matter Penalties**
  - **Broadcast**
  - Preservation
  - Inscription Energy
  - Deceleration @Target
  - Navigation
  - Advertisement

Is Radiation Better for Broadcast?

Milky Way stellar density 2.8×10^{-2} stars (LY)$^{-3}$

Assume spherical galaxy, omnidirectional transmission, Arecibo receiver

$T = 3^o K$, $\tilde{\rho} = 10^{22}$, $\delta = \frac{c}{v} = 10^3$



$D = 10^4$ LY: 1.17×10^{11} stars (but $\Omega > 10^{25}$)

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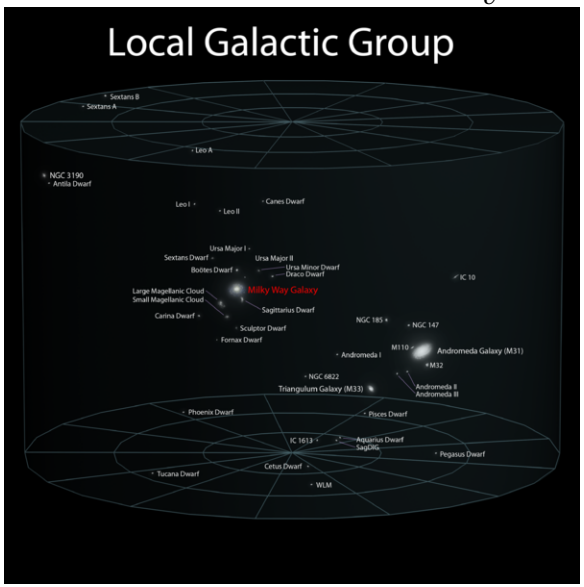

$D = 10^6$ LY: 1.17×10^{17} stars (but $\Omega > 10^{29}$)

Is Radiation Better for Broadcast?

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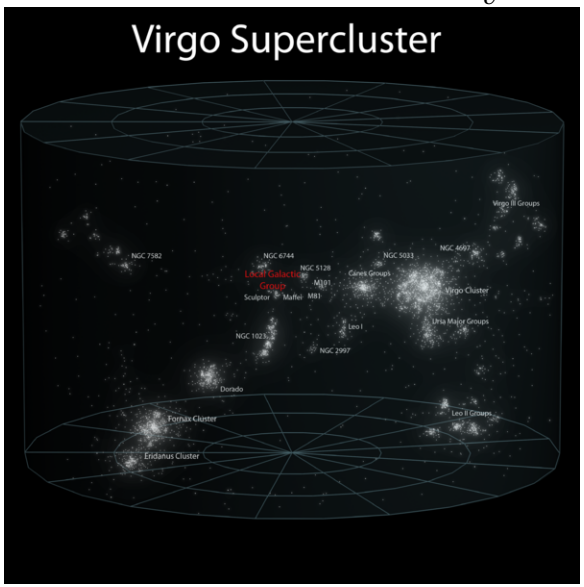

$D = 10^7$ LY: 1.17×10^{20} stars (but $\Omega > 10^{31}$)

Is Radiation Better for Broadcast?

Milky Way stellar density 2.8×10^{-2} stars (LY)$^{-3}$

Assume spherical galaxy, omnidirectional transmission, Arecibo receiver

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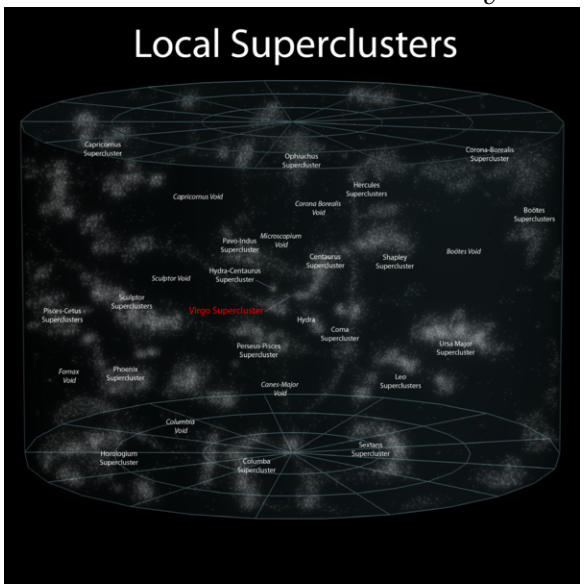


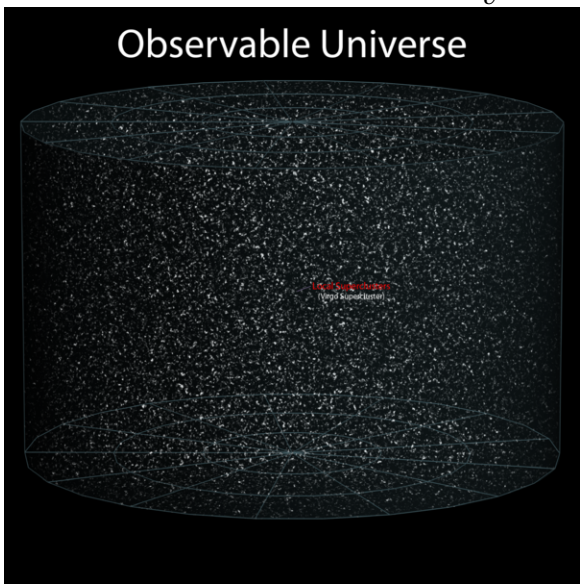
$D = 10^8$ LY: 1.17×10^{23} stars (but $\Omega > 10^{33}$)

Is Radiation Better for Broadcast?

Milky Way stellar density 2.8×10^{-2} stars (LY)$^{-3}$

Assume spherical galaxy, omnidirectional transmission, Arecibo receiver

$T = 3^o K$, $\tilde{\rho} = 10^{22}$, $\delta = \frac{c}{v} = 10^3$



$D = 10^{10}$ LY: 1.17×10^{29} stars (but $\Omega > 10^{37}$)

Appropriately Awed Response

A Big Big Question

A Big Big Question

Why

A Big Big Question

Why

Communicate

A Big Big Question

Why Communicate AT ALL?

Alien Psychology 101

Alien Psychology 101

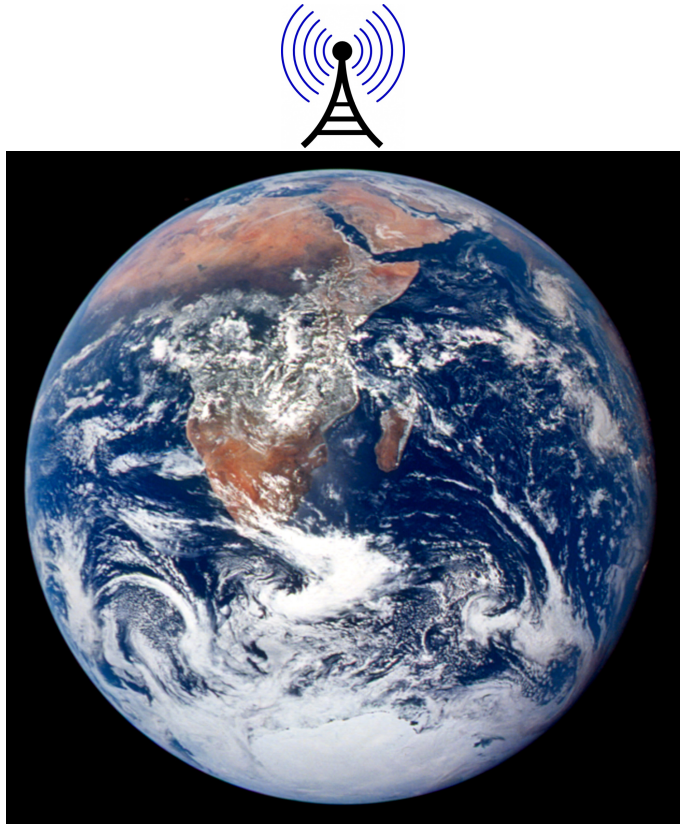
Sociability?

Hello Exoplanet-ling!

IF U CN RD THS, join the party!
Turn left at ...

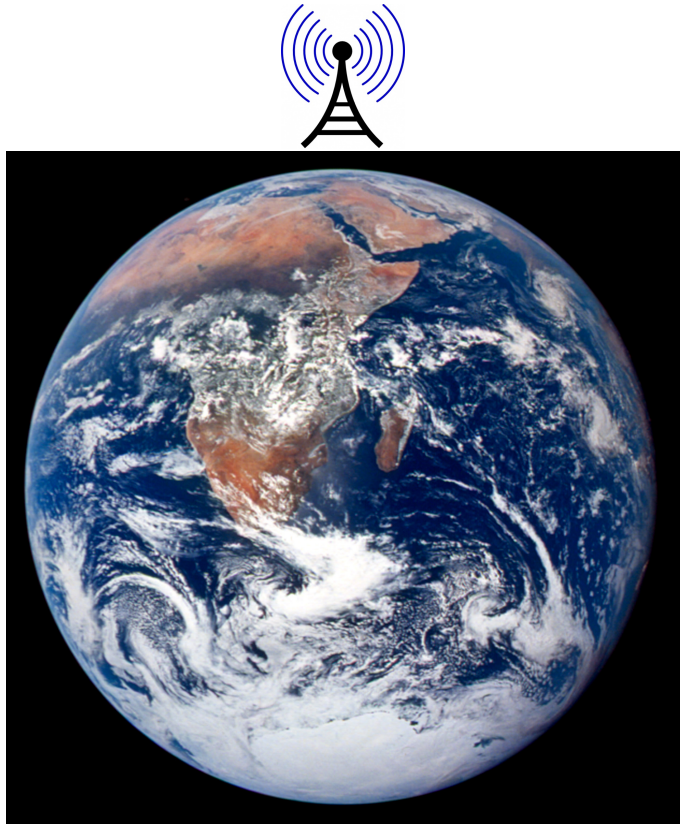
Let Us Help You!

Hello Universe!



Bring technology!

Hello Universe!



Bring technology!

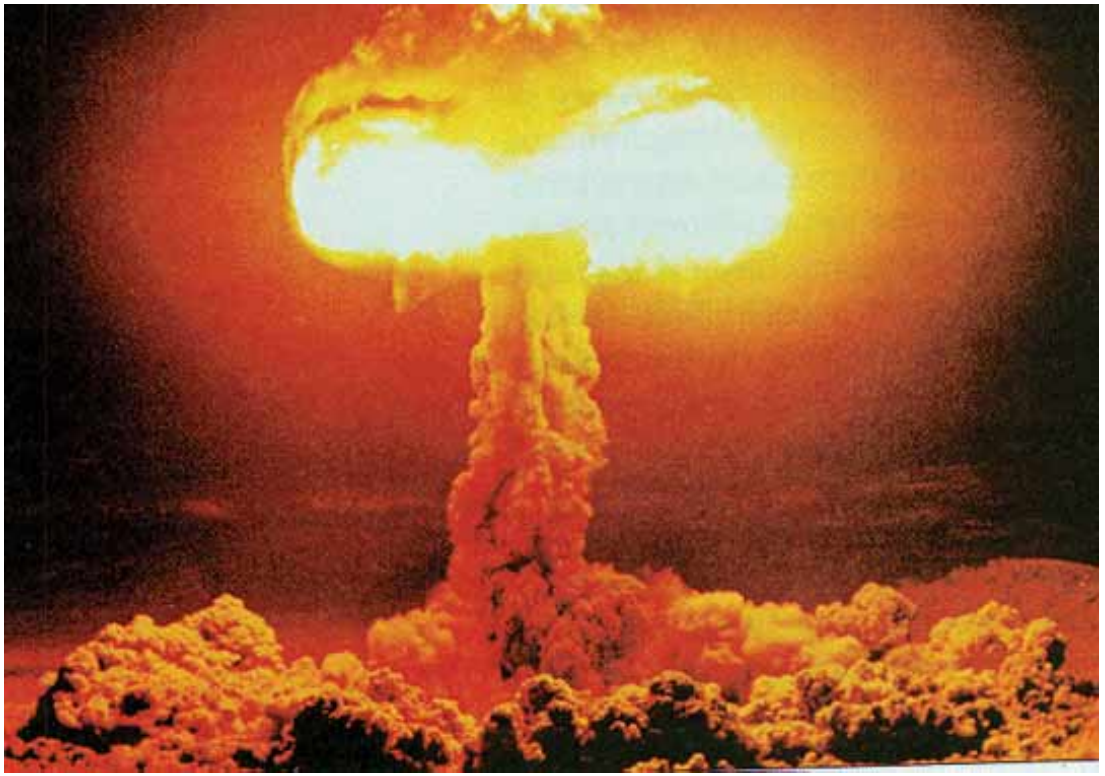
(but, please don't eat us)

Universal (well, galactic) Truth

Universal (well, galactic) Truth

Survival?

OOPS!



OUCH!

RAPTURE!

(sorry, I couldn't resist)

I'm Going With Survival

I'm Going With Survival

SURVIVORS: Those Who Write

I'm Going With Survival

SURVIVORS: Those Who Write

GAME OVER: Those Who Don't

I'm Going With Survival

SURVIVORS: Those Who Write

GAME OVER: Those Who Don't

Is "Biological" Info Transmission SOP?

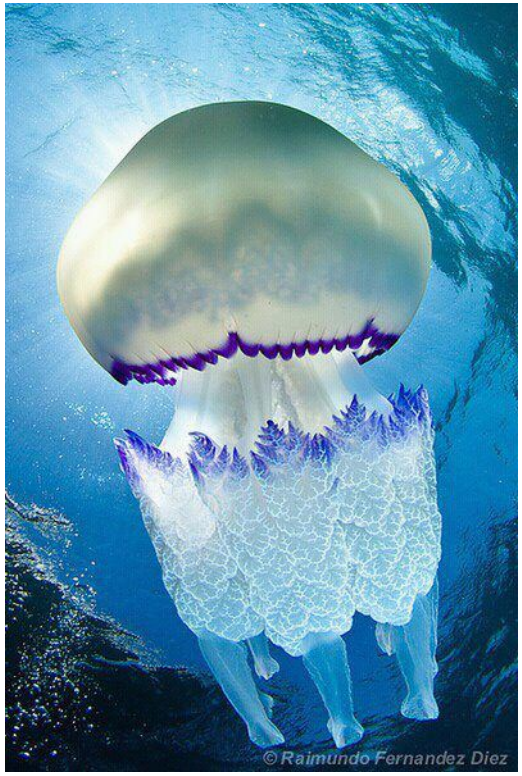
Special Deliveries

Detection

Detection

HOW?

Incursion or Evolution?



Killjoy Biologists

“It’s all one show”

–Gerald Joyce

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“X$\rightarrow$ Y? Evolution!”

–Biological Dogma

Three Fundamental Questions

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(A:) What's (X) alive and here today?

Three Fundamental Questions

(A:) What's (X) alive and here today?

(B:) How easily/quickly $X \rightarrow Y$?

Three Fundamental Questions

(A:) What's (X) alive and here today?

(B:) How easily/quickly $X \rightarrow Y$?

(C:) How many packages?

A & B?

A & B?

A & B?

I

DO

A & B?

I
DO
NOT

A & B?

I
DO
NOT
KNOW

A & B?

I
DO
NOT
KNOW

(hard to frame the problem)

C: Package Density

$$N_p = P f_\ell \lambda_p \tau_p$$

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N_p : number of parcels floating around
P: number of planets
f_ℓ : fraction with loquacious intelligent life
λ_p: parcels/year
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$$P \approx 10^{11} \text{ (NASA)}$$
$$\tau_p = 10^8 \text{ (“geologic” design, galaxy-spanning @ } c/1000)$$
$$\lambda_p f_\ell \approx 1 \text{ (loquacity balancing pessimism)}$$

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$P \approx 10^{11}$ (NASA)
$\tau_p = 10^8$ ("geologic" design, galaxy-spanning @ $c/1000$)
$\lambda_p f_\ell \approx 1$ (loquacity balancing pessimism)

Parcels per star: $\sim 10^8$

Punchline

It seems the 'Sounds of Earth' gold disks aboard Voyagers 1 and 2 (see cover) were on the right track. The message-in-a-bottle idea of sending physical objects across space is highly energy efficient, and **we should search for artefacts in the Solar System now***.*

– **Nature** Editors

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But ...

Maybe We Should Seed Too