Writing for Survival, Reading the Signs

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Rutgers University, WINLAB

Communication Theory Workshop
June 24, 2013

PHYSICIST



Communication Engineer/Theorist



But EVERYTHING Communicates!

But EVERYTHING Communicates!

Particles
Atoms
Cells
Organisms
People
Ecologies
Economies
Universe

But EVERYTHING Communicates!

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Comm Theory is central to BIG questions!

AND ...

But EVERYTHING Communicates!

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Comm Theory is central to BIG questions!

AND ...

Comm Theory built wireless and the Internet!!

Popular Culture



Tricia Rose



Stephanie Bell-Rose



S. James Gates



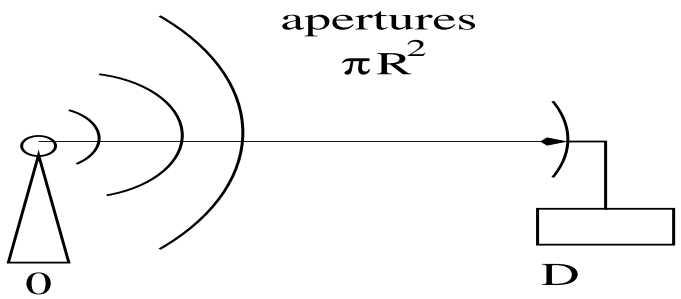
National Medal of Science 2011 (awarded 2013)

Down the Rabbit Hole

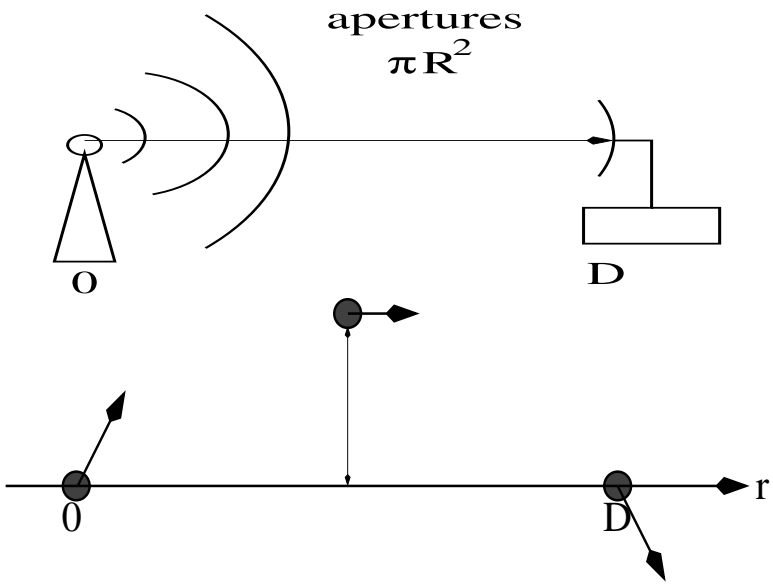
A truck filled with storage media, driven across town, is a very reliable high bit rate channel.

– Communication Theory Zeitgeist

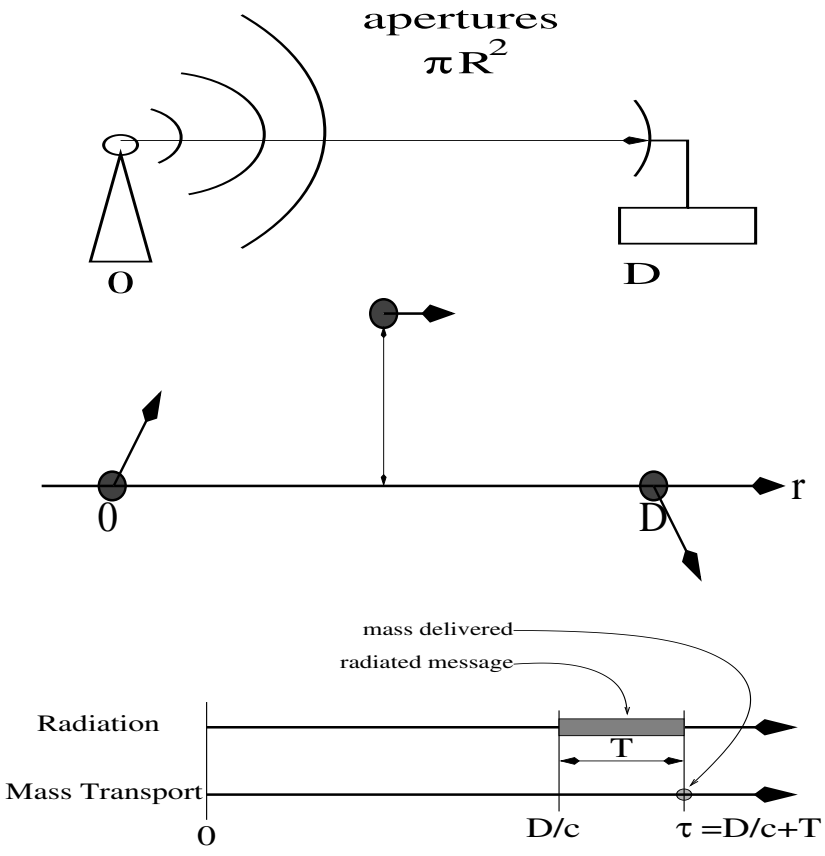
A Little Analytic Rigor



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Radiation Energy Requirements

- **Shannon Capacity:** $C = B/T = W \log_2 \left(\frac{P}{N_0 W} + 1 \right)$

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- Large TW:

$$\boxed{\mathcal{E}_r \geq BN_0\left(\frac{4\pi D^2}{AG}\right)\ln 2}$$

Writing Energy Requirements (ROCKET SCIENCE!)

$$\mathcal{E}^* = \min_{\text{trajectory}} \max_{t} \mathcal{E}(t)$$

Jensen's Inequality Leads To

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$$\mathcal{E}^* = \frac{1}{2} m \bar{v}^2$$

Inscribed Matter Energy Requirements

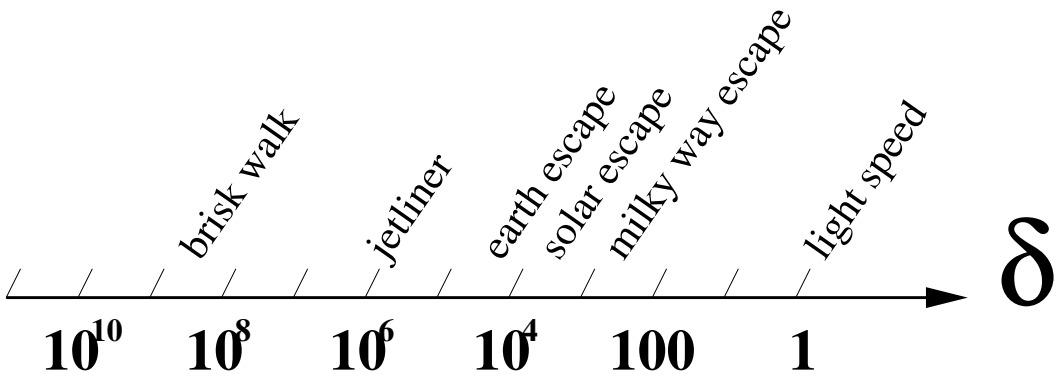
Message size B bits, mass information density $\tilde{\rho}$ bits/kg

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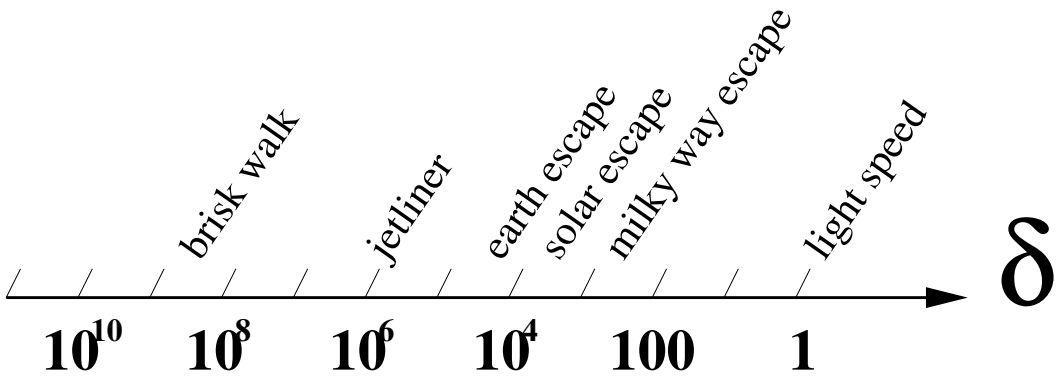
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Artillery: adds a factor of 2 to energy
Escape: small penalty if $\bar{v} > 2 \times$ escape velocity

Radiation to Transport Energy Ratio

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

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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 $\equiv \mathcal{D} = \frac{D}{2R}$

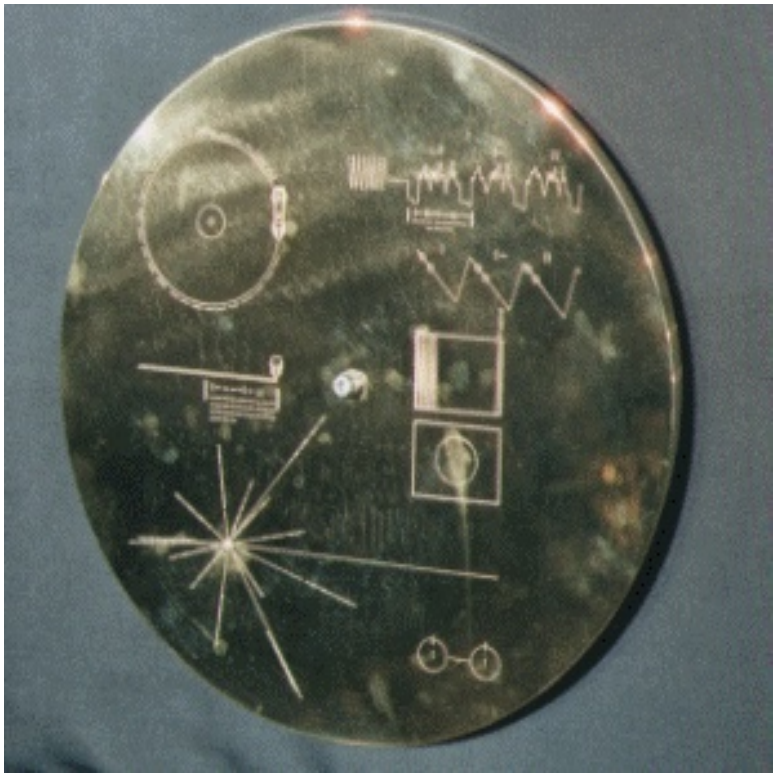
$$\Rightarrow \boxed{\Omega \geq \left[\frac{\tilde{\rho} N_0}{c^2}\right] \left[\frac{8}{\pi^2}\left(\frac{\mathcal{D}}{\mathcal{A}}\right)^2\right] (2\ln 2)\delta^2} \Leftarrow$$

Equal Receiver/Transmitter Apertures

Empirical Mass Information Densities I

Voyager Spacecraft: 10^6 bits/kg





Empirical Mass Information Densities II

- **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

Voyager Existence Proof

- 10^9 bit payload
- 900 kg mass
- Catapult launch: about 800 joules/bit

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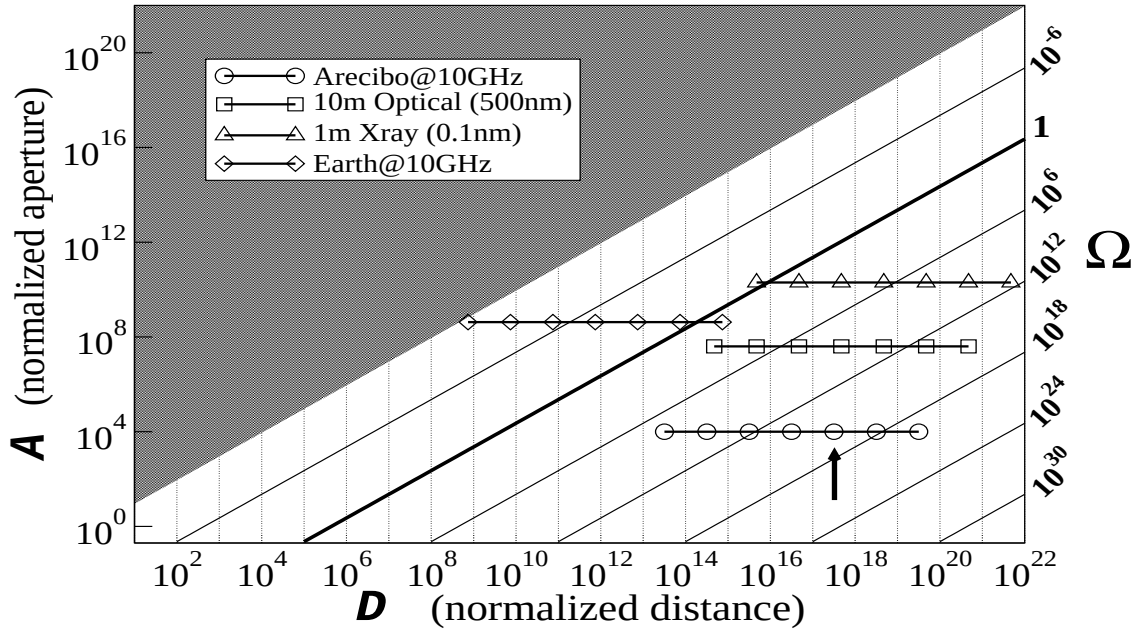
- Asides:
  - ETA nearest star: ≈ 100 kilo-years
  - Rocket Launch: distance up $\times 9$.
  - Use 3 DVDs (instead of gold disc): distance down $\times 10$
  - Use 1 gram of "RNA": distance down $\times 10^6$
    ($\approx 1/4000$ distance to nearest star)

General Interstellar

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

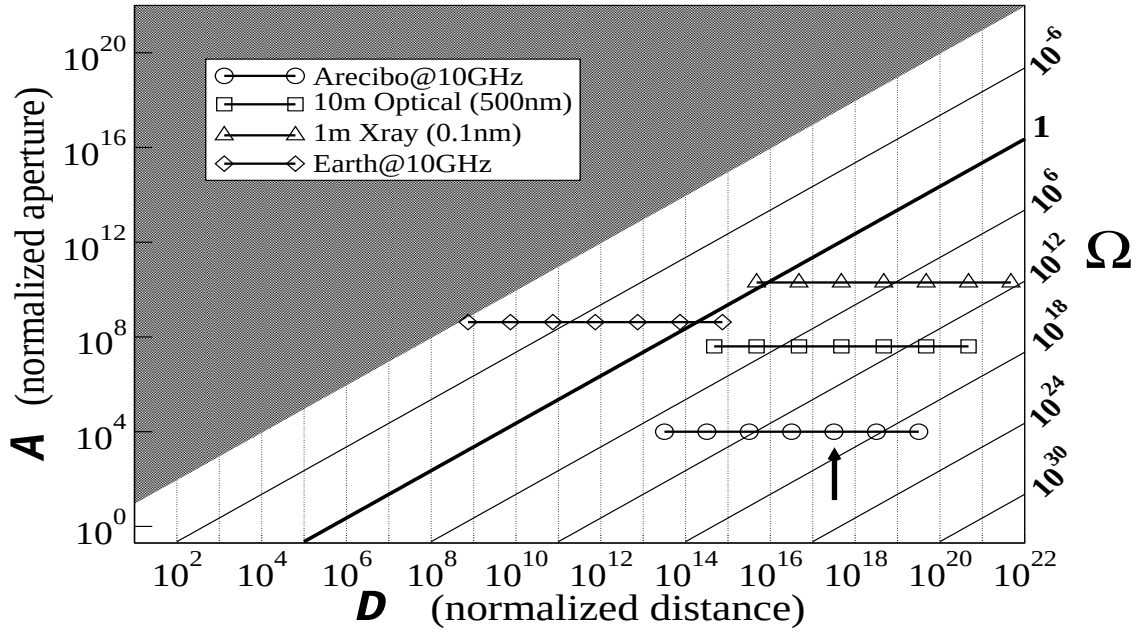
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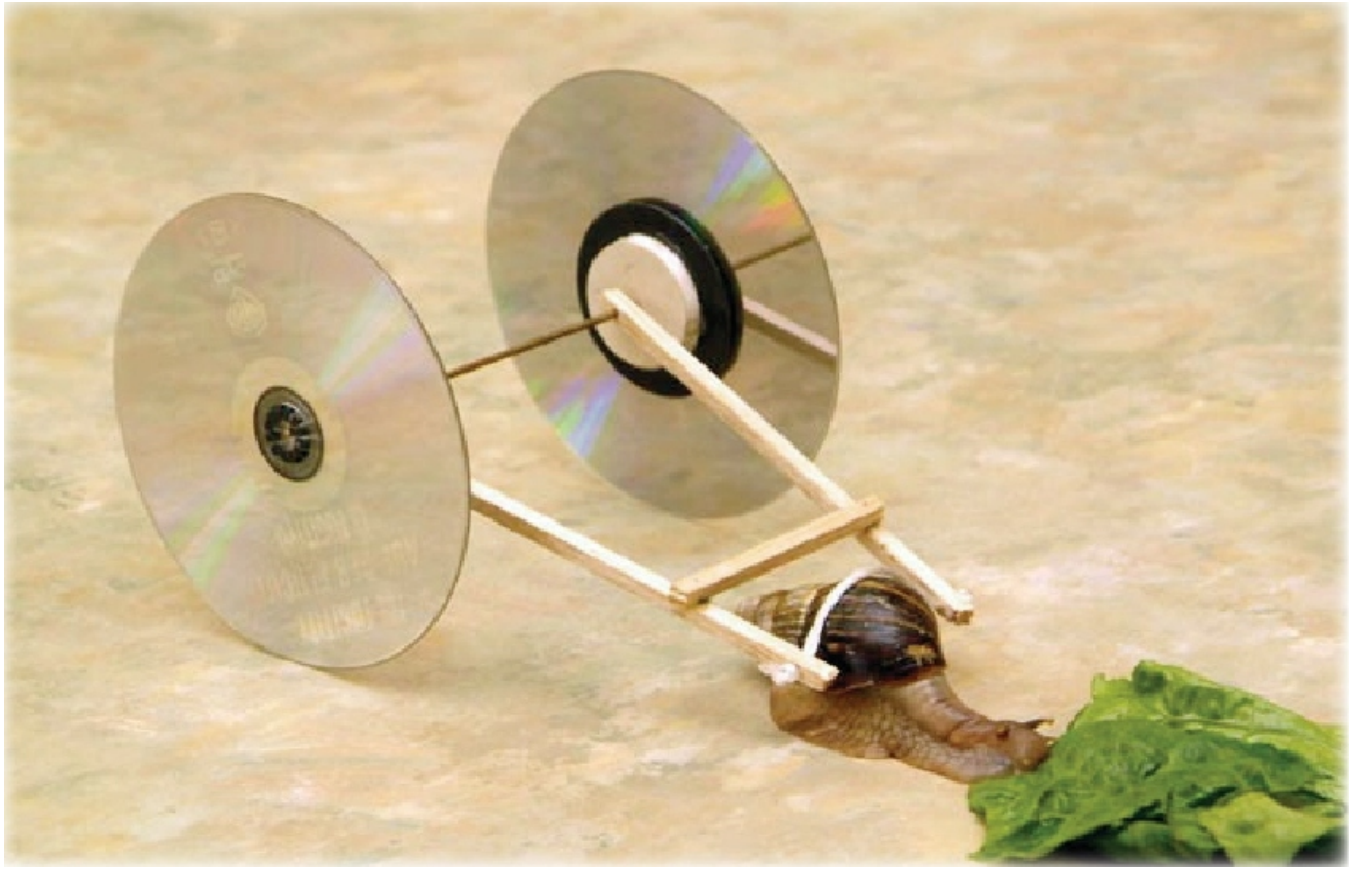


Matter / Radiation: **Shelve a 5 lb sugar bag / 24 Megaton blast**

Communications Theory Has Spoken

If delay can be tolerated, inscribed matter is *stunningly* more energy-efficient than radiation

Sluggish Data vs. ADSL



Annals of Improbable Research 11(4), 2005

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)$^{-3}$
- ($T = 3^o K$, $\tilde{\rho} = 10^{22}$, $\delta = \frac{c}{v} = 10^3$) spherical galaxy, omnidirectional transmission, Arecibo receiver

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Visible Universe: $D = 1.37 \times 10^{10}$ LY

Semaphored and Summarized In ...



Nature 431, pp.47–49, September 2, 2004 (C. Rose & G. Wright)
Web Site: http://www.winlab.rutgers.edu/∼crose/cgi-bin/cosmicP.html

Really Chill Perqs!

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- **NPR** & **BBC** radio interviews
- **NY Times** article by Overbye!
- **NY Times** Editorial!!
- Cocktail party banter!!!

Not So Chill Perqs

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Counsel: Dr. Rose, what term of address would you prefer?
Rose: “Chris” is fine.
Counsel: These are formal proceedings, so I’ll use “Dr. Rose,” okay?
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Counsel: Are you a professor of E&CE at Rutgers University?
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Counsel: **Dr. Rose, do you talk to space aliens?**
Rose: *(WTH?!?!?!?!)....*

More Reasonable Questions

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Do I READ alien letters?

More Reasonable Questions

Do I READ alien letters?

Why communicate AT ALL?

Alien Psychology 101

Alien Psychology 101

Sociability?

Hello Exoplanet-ling!

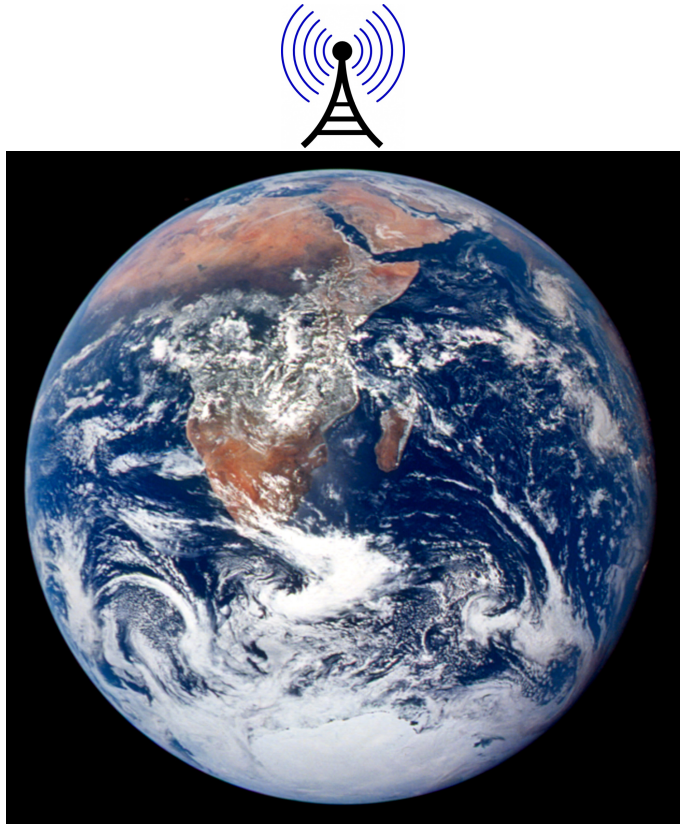


IF U CN C THS, join the party!
Turn left at Alpha Centauri ...

Let Us Help You!

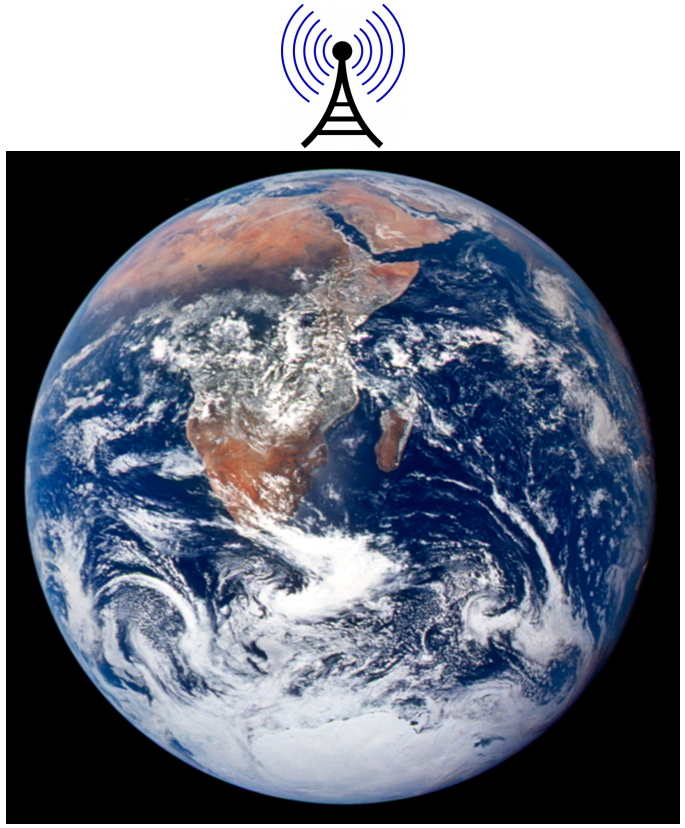


Hello Universe!



Bring technology!

Hello Universe!



Bring technology!

(but, please don't eat us)

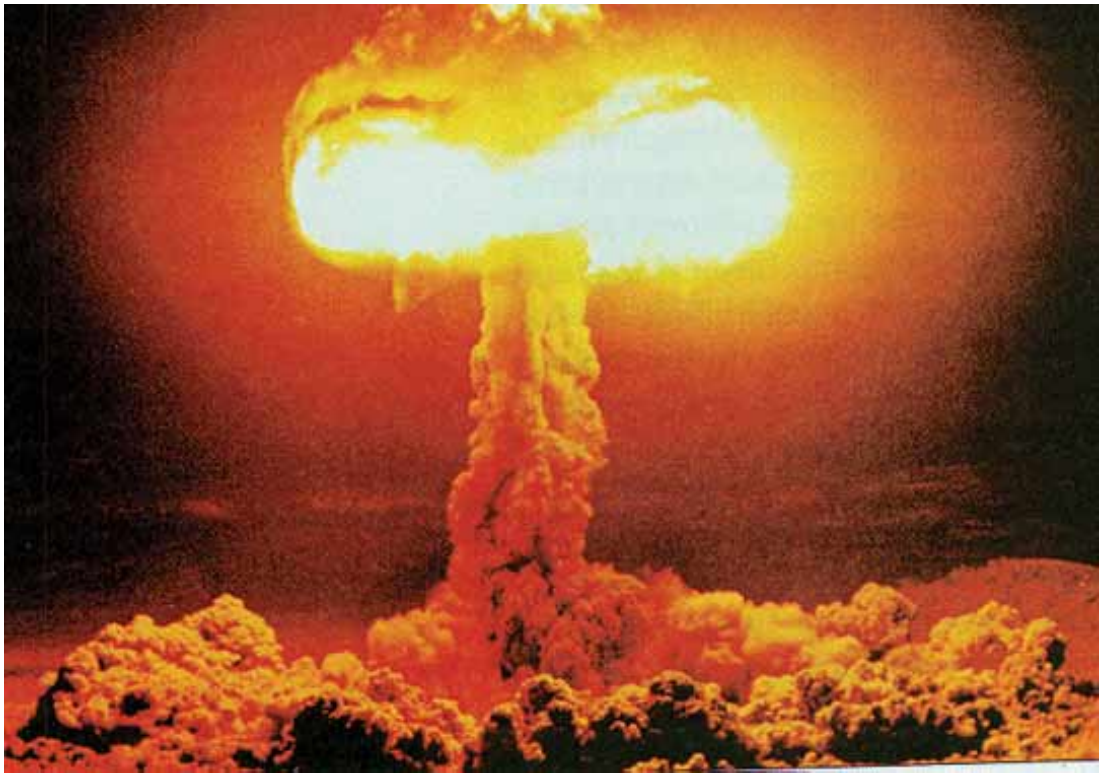
Universal (well, galactic) Truth

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Survival?

OOPS!





OUCH!



RAPTURE!



(sorry, I couldn't resist)

Interstellar "Evolution"

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SURVIVORS: Those Who Write

Interstellar "Evolution"

SURVIVORS: Those Who Write

GAME OVER: Those Who Don't

Interstellar "Evolution"

SURVIVORS: Those Who Write

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Is Biological Info Transmission SOP?

Seeded Comet?



Micro Ark?



Are we THERE YET!?!?

Sorry, (your) Game Over!



Detection

Pipe Dream? (50+ Years of SETI)



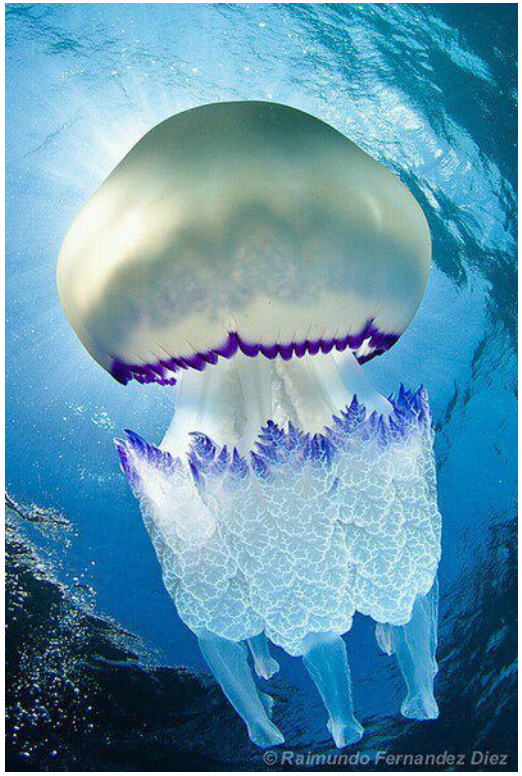
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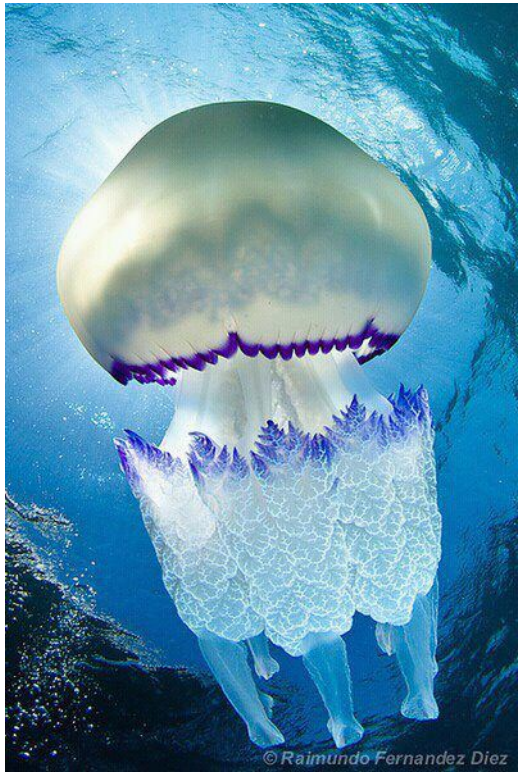
Could be, but ... let's play anyway

Incursion or Evolution?





Incursion or Evolution?





Cambrian explosion – which?

Killjoy Biologists

“It’s all one show”

–Gerald Joyce

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“X$\rightarrow$ Y? Evolution!”
–Biological Dogma

Can We Detect Ancient Biological Incursions?

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I DO NOT KNOW!

I might never know!

(Plenary talk sales final – **Absolutely No Refunds!**)

Can We Detect Future Biological Incursions?

Can We Detect Future Biological Incursions?



ET!



or EGAD!

Three Fundamental Questions

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(A:) How many packages?

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(B:) What's here today?

Three Fundamental Questions

(A:) How many packages?

(B:) What's here today?

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

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$$N_p = P f_e f_\ell f_i f_c \lambda_p \tau_p$$ (After Drake – Fermilicious and equally fake)

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Parcels per star: 3.33×10^7

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- Aviation: 2% yearly global CO_2
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Not a (too) ridiculous detection problem

(C): Quantitative Evolution

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Setup:

- String ("gene") set $\mathcal{G} = \{\mathbf{g}_n\}$, $n = 1, \cdots, N$
- $\mathbf{g}_n = [b_{n_1}, \cdots, b_{n_K}]$, $b_i \in \{A, T, G, C\}$
- Target string $\mathbf{T}$
- Evolution (mutation/crossover) operators $\{\mathcal{M}_q\}$

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- **Likelihood:** what $\mathcal{G} \rightarrow \mathbf{T}$ paths are preferred? How long/short?

Is This Communication Theory?

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Information Delivery and Control ✓

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Genome Measurment: Sampling/Detection ✓

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Genome Representation: "Signal" Space ✓

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Mutation/Mating Trellis: hey, it's a TRELLIS! 

Communication Theorists



PWN the BIG questions!