Writing for Survival, Reading the Signs
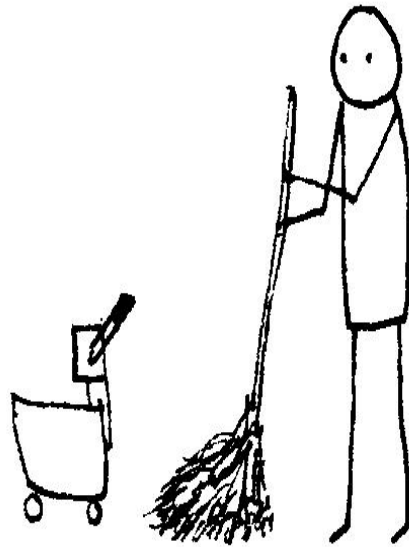
Christopher Rose

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!

Particles

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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

Most Powerful Women in New York 2007

Stephanie Bell-Rose ◄ ►

Goldman Sachs Foundation

Stephanie Bell-Rose grew up in poor neighborhoods in Brooklyn and on Long Island. But that didn't stop her from helping others. She started volunteering at age 14, working summers at a day care center and a nursing home.

"Both of my parents were committed to service for the improvement of the lives of others," she says. "That was a part of our family ethos, and I absorbed it from my earliest days."

And when she earned a scholarship to Harvard University, Ms. Bell-Rose never hesitated about her

Recommend 0 Share

4 of 100
(Click photo to view next slide)

DO YOU HAVE WHAT IT TAKES TO BE A CRAIN'S TOP ENTREPRENEUR
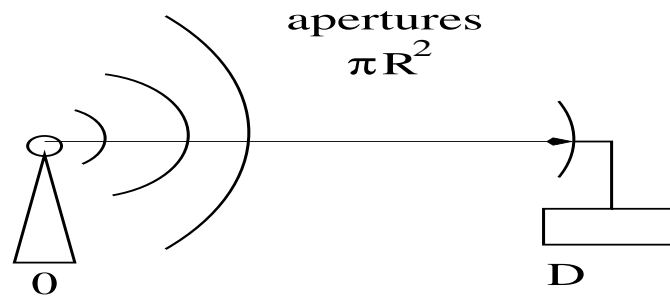
CRAIN'S NEW YORK BUSINESS

S. James Gates

National Medal of Science 2011 (awarded 2013)
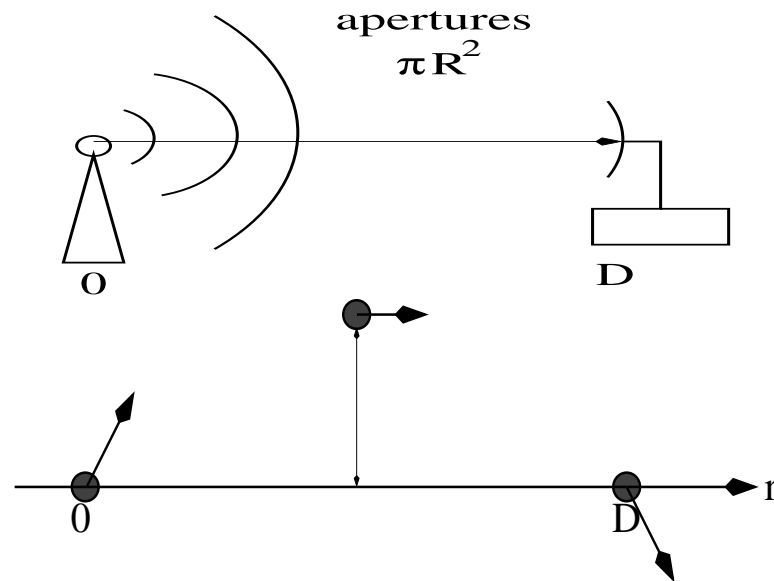
Down the Rabbit Hole

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

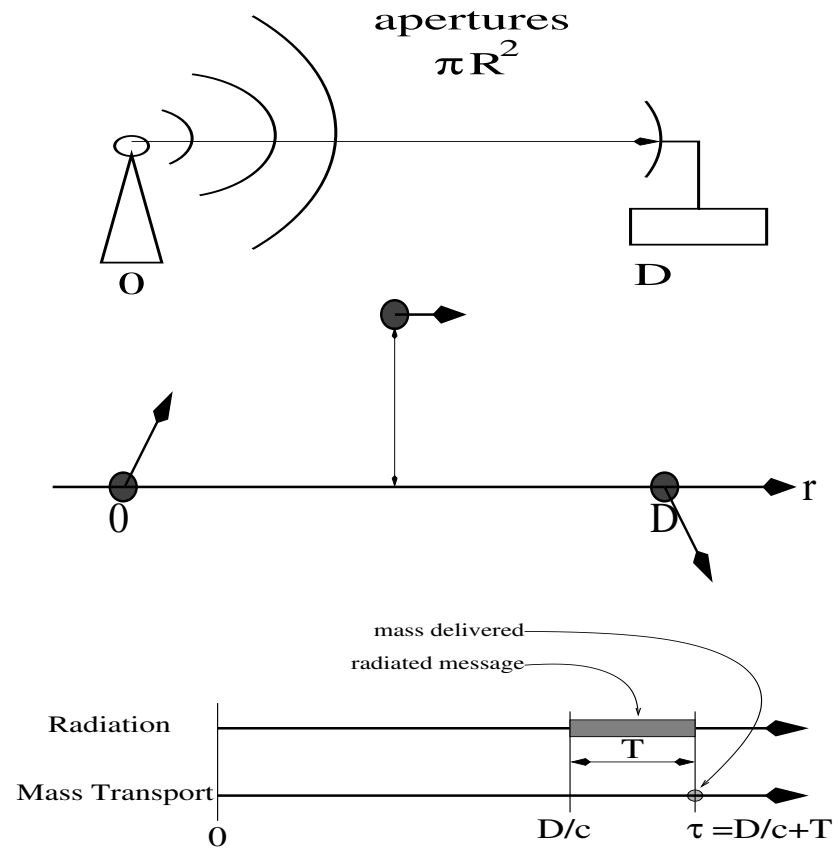– Communication Theory Zeitgeist

A Little Analytic Rigor

apertures
πR^2

O

D

A Little Analytic Rigor

A Little Analytic Rigor

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:

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

Writing Energy Requirements (ROCKET SCIENCE!)

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

Jensen's Inequality Leads To

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Jensen's Inequality Leads To

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

Inscribed Matter Energy Requirements

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

$$\mathcal{E}_w = \frac{1}{2}\frac{B}{\tilde{\rho}}\bar{v}^2 = \frac{1}{2}\frac{B}{\tilde{\rho}}\left(\frac{c}{\delta}\right)^2$$
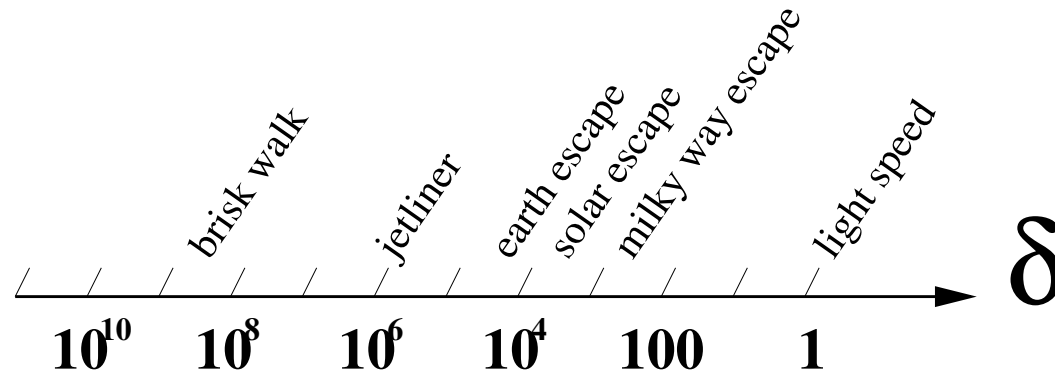
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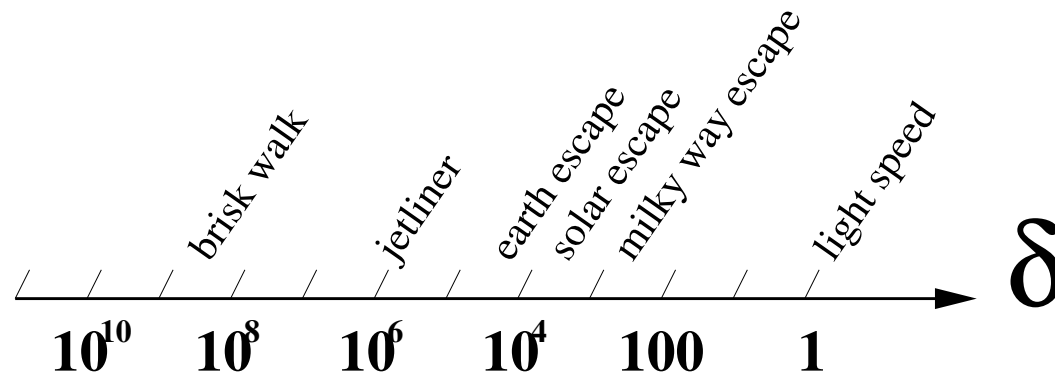
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Artillery: adds a factor of 2 to energy
Escape: small penalty if $\bar{v} > 2 \times$ escape velocity

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 $\equiv \mathcal{A} = \frac{2R}{\lambda}$
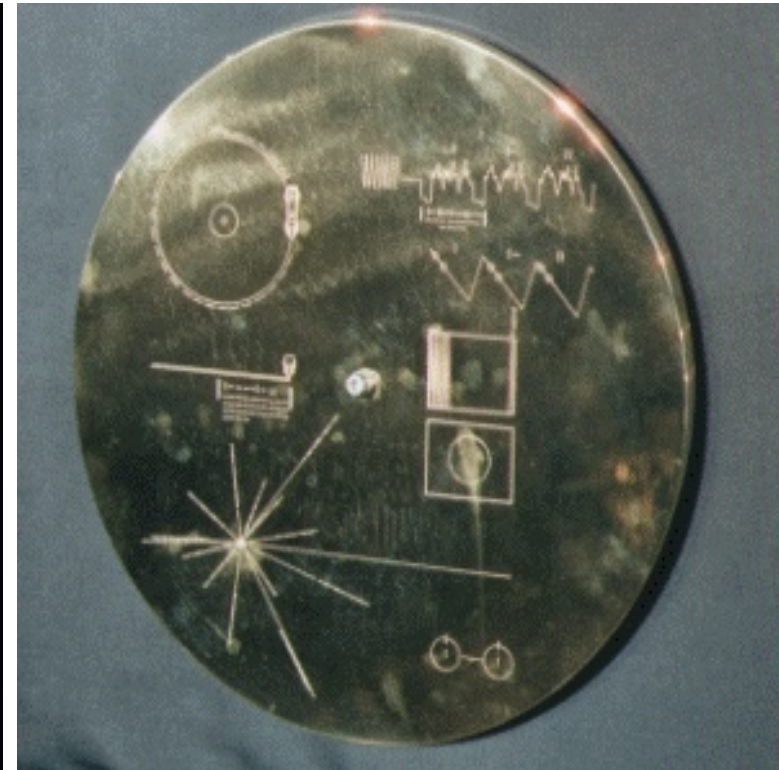
Normalized Distance $\equiv \mathcal{D} = \frac{D}{2R}$

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

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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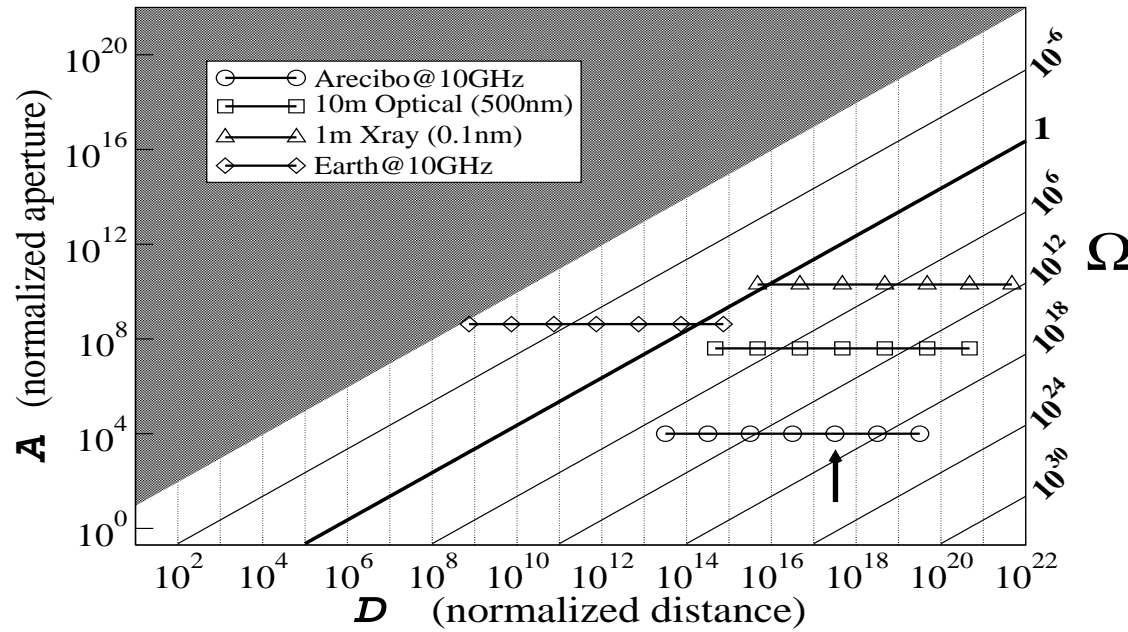## Breakeven Distance: ≈ 2000 light years

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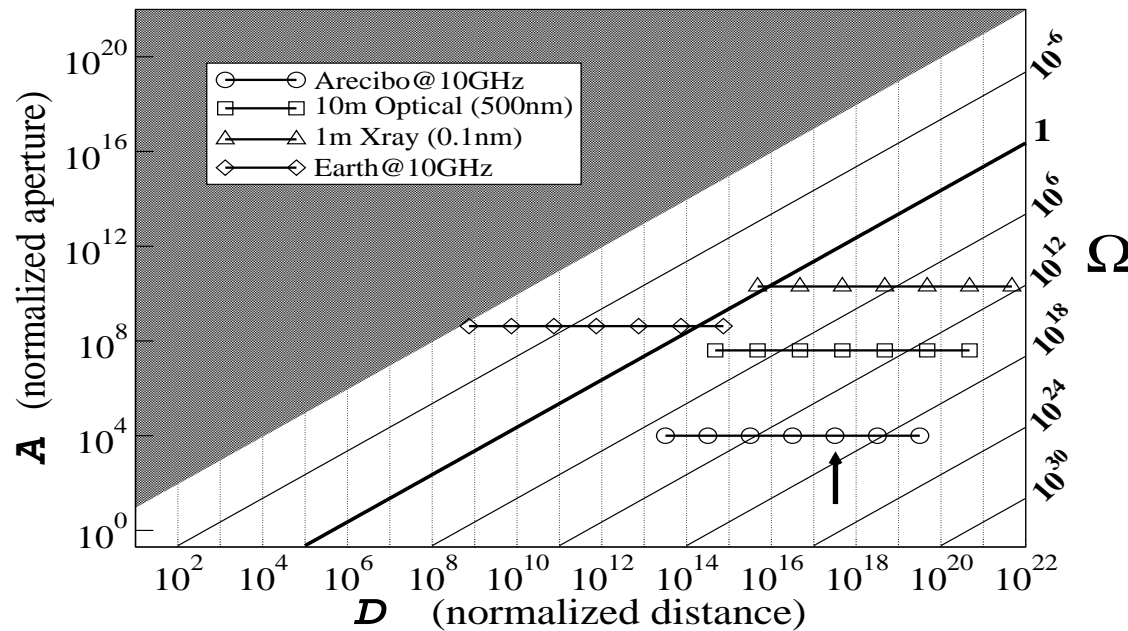
Matter : **Shelve a 5 lb sugar bag**
Radiation : **24 Megaton blast**

Communications Theory Has Spoken

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

Sluggish Data vs. ADSL
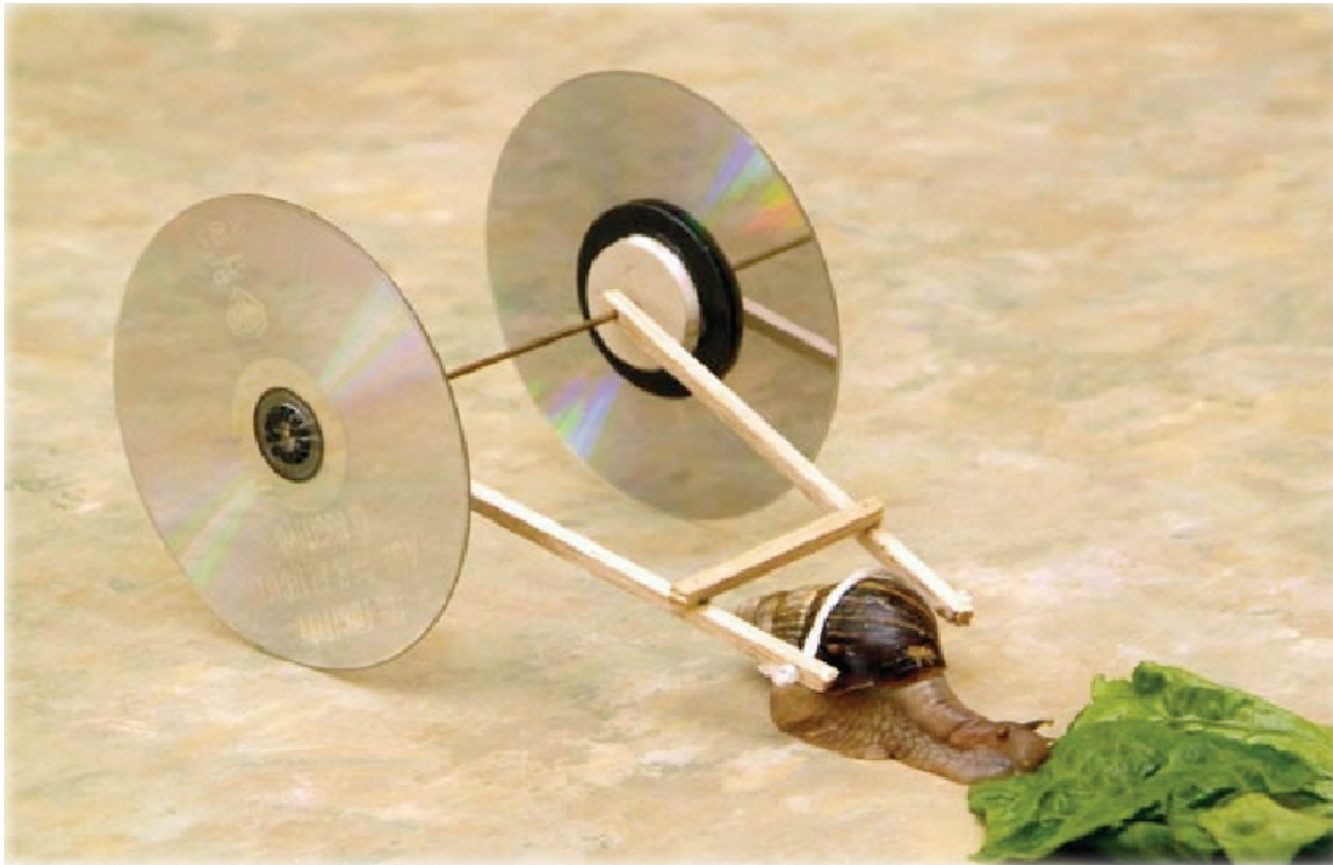
Annals of Improbable Research 11(4), 2005

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!

Really Chill Perqs!

- **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.
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Counsel: Dr. Rose, do you talk to space aliens?
Rose: *(WTH?!?!?!?!)....*

More Reasonable Questions

More Reasonable Questions

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

Universal (well, galactic) Truth

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

GAME OVER: Those Who Don't

Is Biological Info Transmission SOP?

Seeded Comet?

Micro Ark?

Are we THERE YET!?!?

Sorry, (your) Game Over!

Detection

Pipe Dream? (50+ Years of SETI)

Detection

Pipe Dream? (50+ Years of SETI)

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

Incursion or Evolution?

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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 $X \rightarrow Y$?

(A): Package Density: the fake equation

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$\tau_p = 10^8$ ("geologic" design, galaxy-spanning @ $c/1000$)

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Parcels per star: 3.33×10^7

(B): Biome Survey/Monitor

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- Aviation: 2% yearly global CO_2

- Aircraft: 111 kg CO_2/km

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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 $\mathcal{G} \to \mathbf{T}$ paths are preferred? How long/short?

Is This Communication Theory?

Is This Communication Theory?

Information Delivery and Control✔

Is This Communication Theory?

Information Delivery and Control ✔

Genome Measurment: Sampling/Detection ✔

Is This Communication Theory?

Information Delivery and Control ✔

Genome Measurment: Sampling/Detection ✔

Genome Representation: "Signal" Space ✔

Is This Communication Theory?

Information Delivery and Control ✔

Genome Measurment: Sampling/Detection ✔

Genome Representation: "Signal" Space ✔

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

Communication Theorists

PWN the BIG questions!