Research Is Just Plain Curiosity (with a dab of math)

Christopher Rose
Rutgers University, WINLAB

Northern NJ Junior Science and Humanities Symposium
March 19, 2012

BUSINESS: Master of the Universe

Research

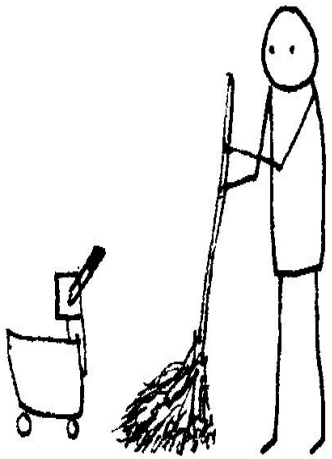
Conversation Starter Fail:

Conversation Starter Fail:

“Hey! I’m a Researcher!”

Physicist

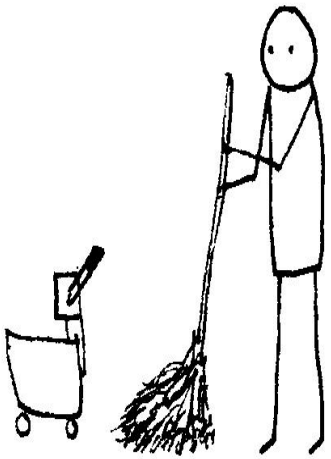
Physicist



$$E = h\nu$$

$$E = mc^2$$

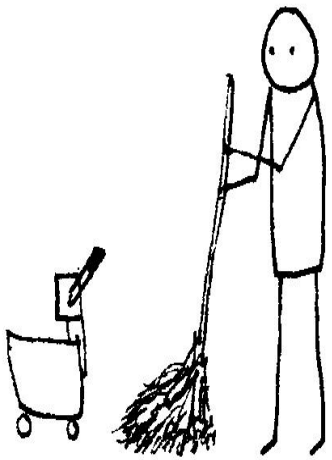
Physicist



$$E = h\nu$$

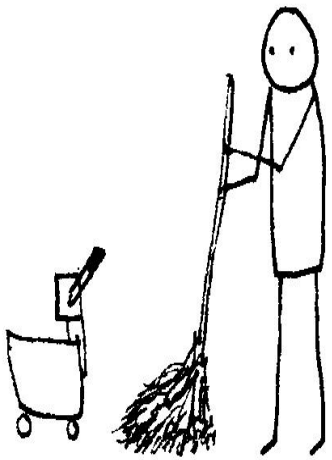
$$E = mc^2$$

Communication/Computer Scientist



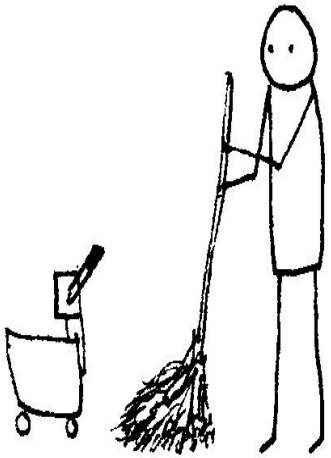
Communication/Computer Scientist

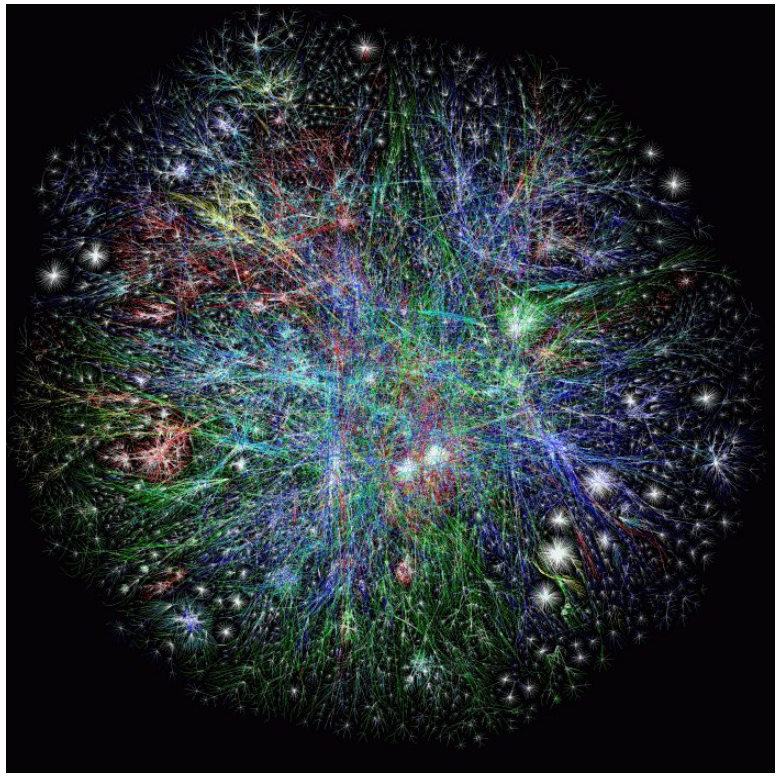
$$W \log\left(1 + \frac{P}{N_0 W}\right) \qquad L = \lambda\tau$$



Communication/Computer Scientist

$$W \log\left(1 + \frac{P}{N_0 W}\right) \qquad L = \lambda\tau$$



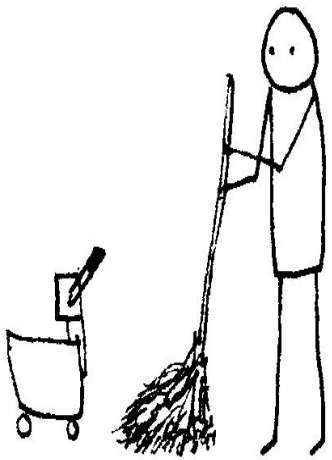


Rutgers Students

Rutgers Students

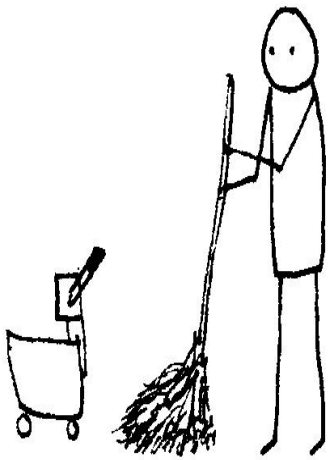
- Bluetooth World Domination

Rutgers Students



- Bluetooth World Domination
- Ant(ennas)s in Your Pants: WiFi hotspot finder

Rutgers Students



- Bluetooth World Domination
- Ant(ennas)s in Your Pants: WiFi hotspot finder
- Kinect Personal Coach

Rutgers Students

- Bluetooth World Domination
- Ant(ennas)s in Your Pants: WiFi hotspot finder
- Kinect Personal Coach
- Refrigulator

Rutgers Students

- Bluetooth World Domination
- Ant(ennas)s in Your Pants: WiFi hotspot finder
- Kinect Personal Coach
- Refrigulator
- Electromyographic “Telepathy”

Personal Wireless I

Personal Wireless I

- Pass out these sheets

Personal Wireless I

- Pass out these sheets
- You'll have a number.

Personal Wireless I

- Pass out these sheets
- You'll have a number.
- Have text? You're a talker (transmitter).

Personal Wireless I

- Pass out these sheets
- You'll have a number.
- Have text? You're a talker (transmitter).
- Only a number? You're a listener (receiver).

Personal Wireless I

- Pass out these sheets
- You'll have a number.
- Have text? You're a talker (transmitter).
- Only a number? You're a listener (receiver).
- Senders identify your receivers.

Personal Wireless I

- Pass out these sheets
- You'll have a number.
- Have text? You're a talker (transmitter).
- Only a number? You're a listener (receiver).
- Senders identify your receivers.
- You have 15 seconds to convey your messages.
- Ready, set ...

Personal Wireless I

- Pass out these sheets
- You'll have a number.
- Have text? You're a talker (transmitter).
- Only a number? You're a listener (receiver).
- Senders identify your receivers.
- You have 15 seconds to convey your messages.
- Ready, set ...**GO!!!**

Personal Wireless II

Personal Wireless II

- Shuffle sheets around a bit.

Personal Wireless II

- Shuffle sheets around a bit.
- Have text? You're a talker (transmitter).

Personal Wireless II

- Shuffle sheets around a bit.
- Have text? You're a talker (transmitter).
- Only a number? You're a listener (receiver).

Personal Wireless II

- Shuffle sheets around a bit.
- Have text? You're a talker (transmitter).
- Only a number? You're a listener (receiver).
- Senders identify your receivers.

Personal Wireless II

- Shuffle sheets around a bit.
- Have text? You're a talker (transmitter).
- Only a number? You're a listener (receiver).
- Senders identify your receivers.
- Transmitters: walk over to your receiver.

Personal Wireless II

- Shuffle sheets around a bit.
- Have text? You're a talker (transmitter).
- Only a number? You're a listener (receiver).
- Senders identify your receivers.
- Transmitters: walk over to your receiver.
- Ready, set ...

Personal Wireless II

- Shuffle sheets around a bit.
- Have text? You're a talker (transmitter).
- Only a number? You're a listener (receiver).
- Senders identify your receivers.
- Transmitters: walk over to your receiver.
- Ready, set ...**GO!!!**

Personal Wireless III

Personal Wireless III

- Transmitters: ball up your paper.

Personal Wireless III

- Transmitters: ball up your paper.
- Receivers: get ready to catch the ball.

Personal Wireless III

- Transmitters: ball up your paper.
- Receivers: get ready to catch the ball.
- Ready, set ...

Personal Wireless III

- Transmitters: ball up your paper.
- Receivers: get ready to catch the ball.
- Ready, set ...**GO!!!**

So, GO POSTAL!

Forget Radio!
Write message down!
Toss it to recipient!

So, GO POSTAL!

Forget Radio!
Write message down!
Toss it to recipient!

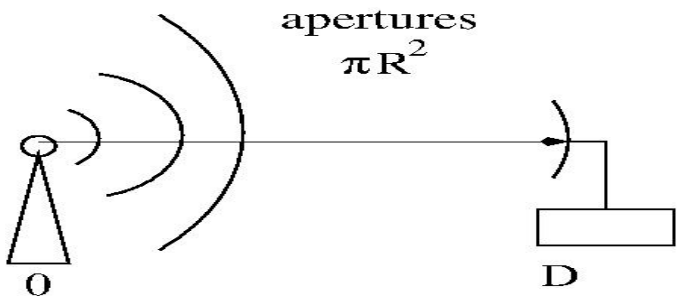
COMPLETELY RIDICULOUS, RIGHT??!!

Look More Closely At What We Think We Know

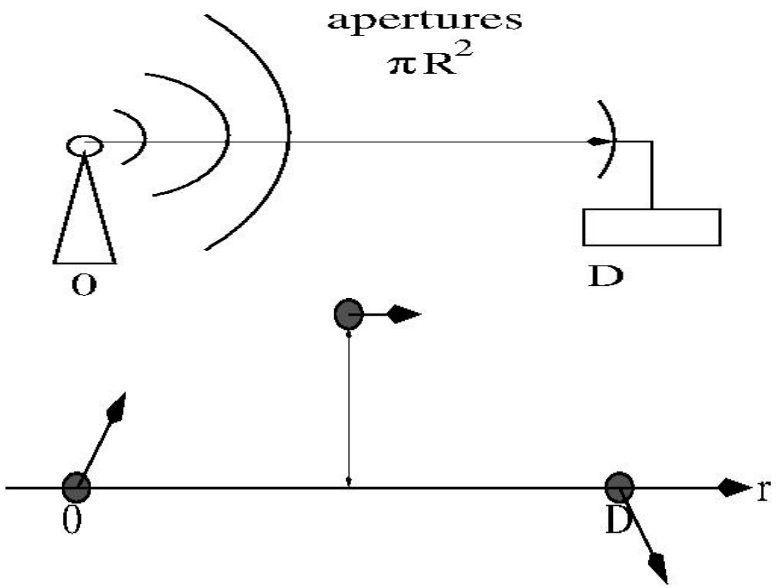
A truck filled with storage media, driven across town, is a very reliable high bit rate channel.

–Comm. Theory Collective Subconscious

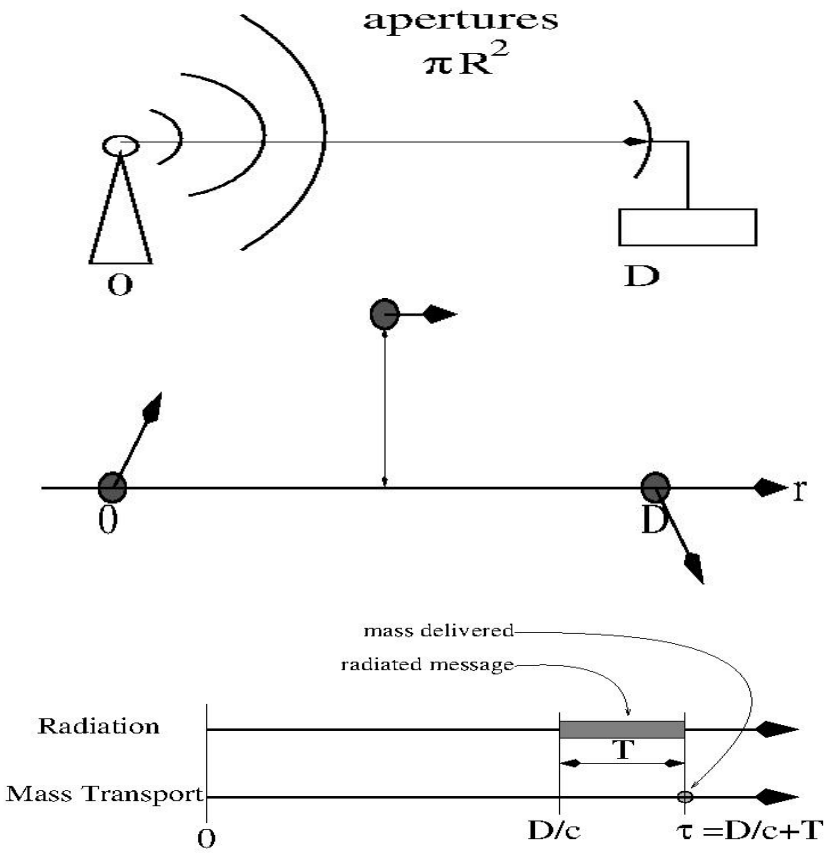
A Little Analytic Rigor



A Little Analytic Rigor



A Little Analytic Rigor



Radiation to Transport Energy Ratio

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

Radiation to Transport Energy Ratio

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

Receiver Noise $\equiv N_0$ Joules/Hz

Mass Information Density $\equiv \tilde{\rho}$ bits/kg

Velocity Ratio $\equiv \delta = \frac{c}{v}$

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

Mass Information Density, $\tilde{\rho}$

Mass Information Density, $\tilde{\rho}$

How About Black Holes?

Mass Information Density, $\tilde{\rho}$

How About Black Holes?

- Schwarzschild Radius: $r = 2GM/c^2 = 1.5X10^{-27}M$
- Info content goes as event horizon *surface area*: $10^{72}r^2$ bits

$$\tilde{\rho} = 1.5 \times 10^{45} r \text{ bits/kg}$$

Mass Information Density, $\tilde{\rho}$

How About Black Holes?

- Schwarzschild Radius: $r = 2GM/c^2 = 1.5X10^{-27}M$
- Info content goes as event horizon *surface area*: $10^{72}r^2$ bits

$$\tilde{\rho} = 1.5 \times 10^{45} r \text{ bits/kg}$$

- Microhole (1μm radius): 1.5×10^{39} bits/kg

Mass Information Density, $\tilde{\rho}$

How About Black Holes?

- Schwarzschild Radius: $r = 2GM/c^2 = 1.5X10^{-27}M$
- Info content goes as event horizon *surface area*: $10^{72}r^2$ bits

$$\tilde{\rho} = 1.5 \times 10^{45} r \text{ bits/kg}$$

- Microhole (1μm radius): 1.5×10^{39} bits/kg
- Donut-hole sized hole (1cm radius): 1.5×10^{43} bits/kg

Mass Information Density, $\tilde{\rho}$

How About Black Holes?

- Schwarzschild Radius: $r = 2GM/c^2 = 1.5X10^{-27}M$
- Info content goes as event horizon *surface area*: $10^{72}r^2$ bits

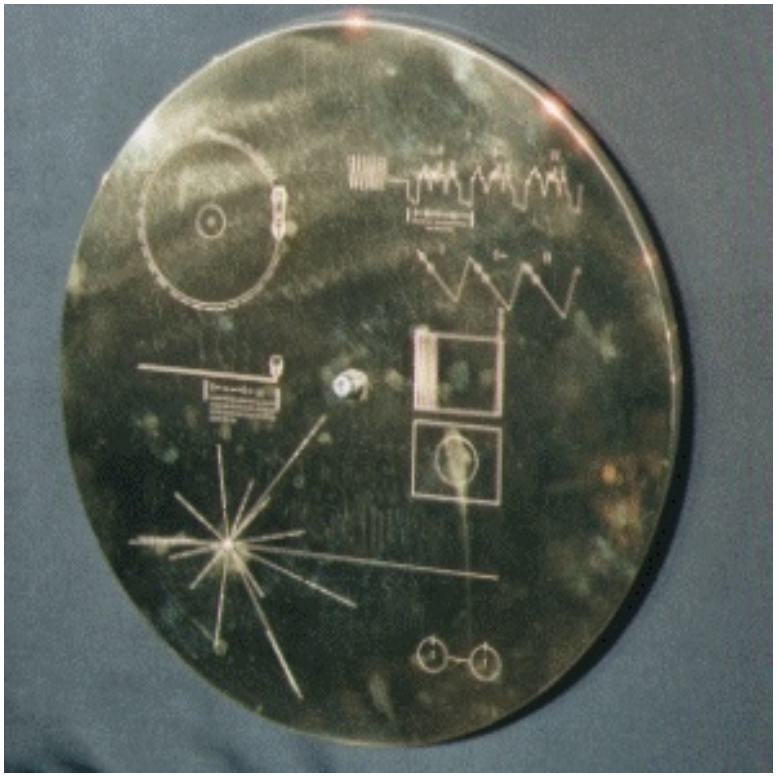
$$\tilde{\rho} = 1.5 \times 10^{45} r \text{ bits/kg}$$

- Microhole (1μm radius): 1.5×10^{39} bits/kg
- Donut-hole sized hole (1cm radius): 1.5×10^{43} bits/kg

VERY antisocial!

Empirical Mass Information Densities I

Voyager Spacecraft: 10^6 bits/kg



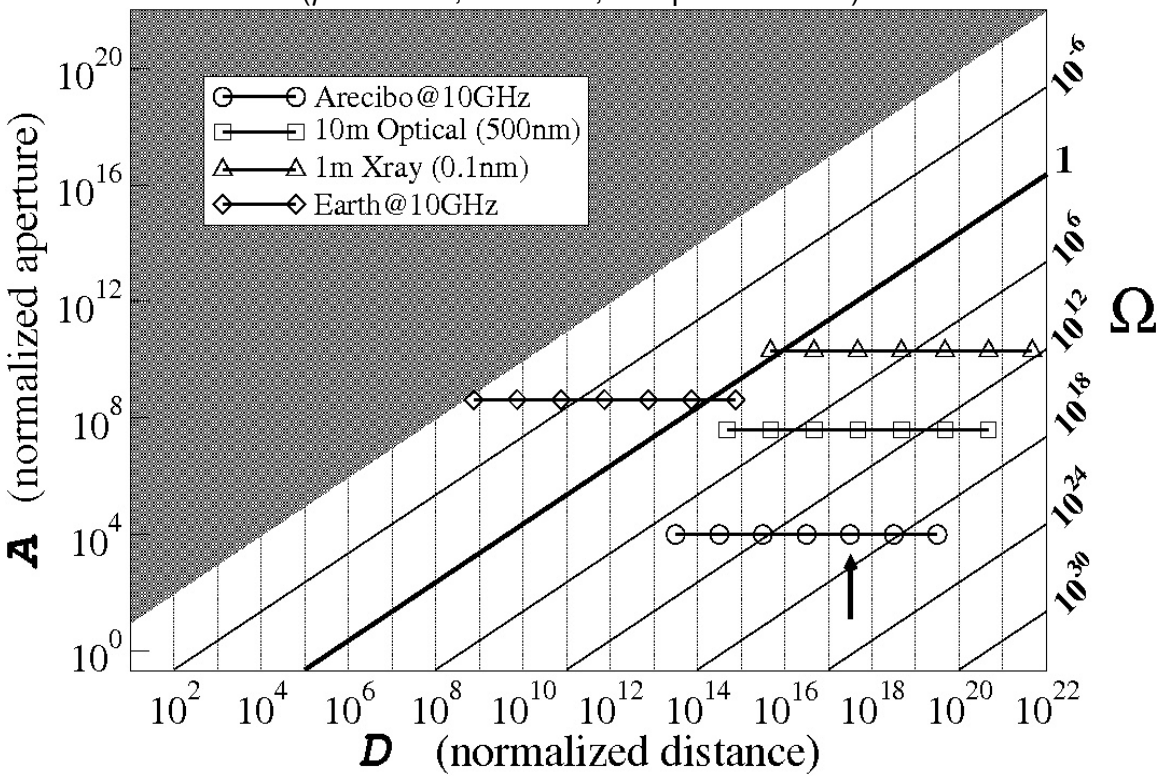
Empirical Mass Information Densities II

- **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

Interstellar

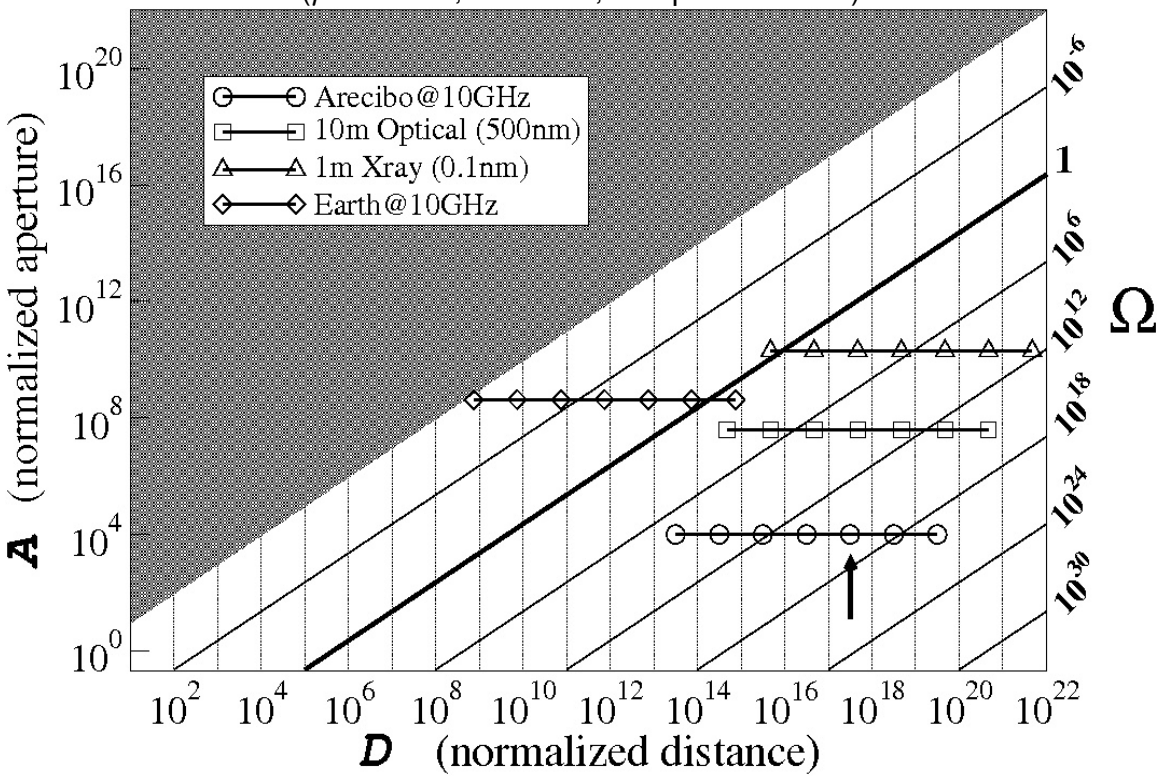
($\tilde{\rho} = 10^{22}$, $\delta = 10^{3}$, Temperature $3K$)



$\longrightarrow$ 10k LY, Arecibo-Arecibo: $\Omega \geq 5 \times 10^{15}$

Interstellar

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



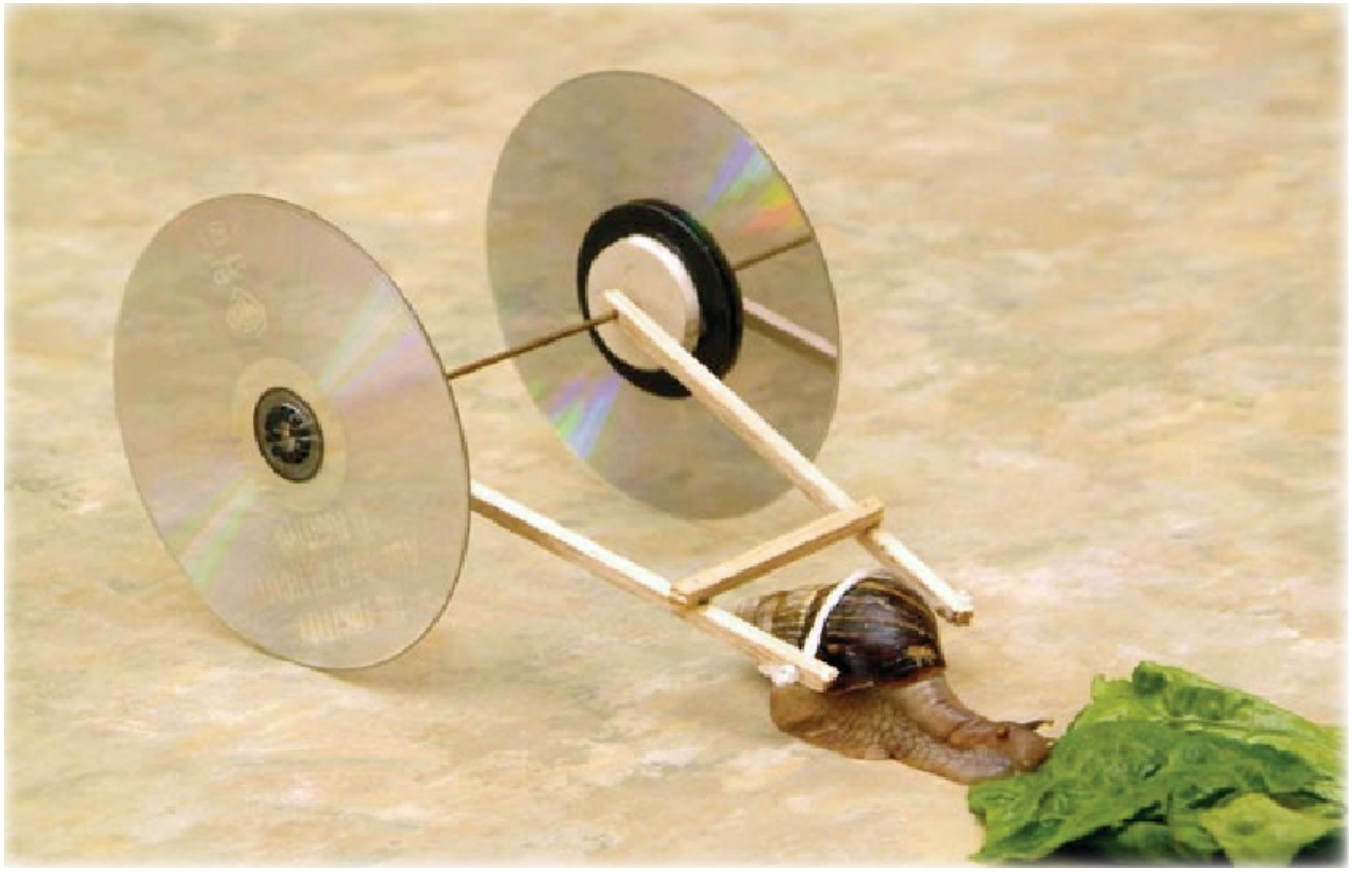
$\longrightarrow$ 10k LY, Arecibo-Arecibo: $\Omega \geq 5 \times 10^{15}$

Radiation/Matter: (24 megaton blast) / (Shelve 5 lb sugar bag)

Communications Theory Has Spoken

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

A Funny Example



Annals of Improbable Research 11(4), 2005

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

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

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

Message Advertisement?

Solar Space is BIG

Big Rock?

Big Rock?

Somewhat antisocial

Odd Rock?

Seeded Comet?

Active Probe?

Micro Ark?

Are we there yet!?!?

CONCLUSION

IF: energy important & delay tolerable
THEN: inscribed matter messaging is efficient

CONCLUSION

IF: energy important & delay tolerable
THEN: inscribed matter messaging is efficient

- Terrestrial
  - FedEx, Netflix, Snail Mail (literally!)
- Chip-to-chip or mote-to-mote
  - smart dust tossing inscribed dust
- Biological systems
  - construction/dispersal cost for messenger molecules

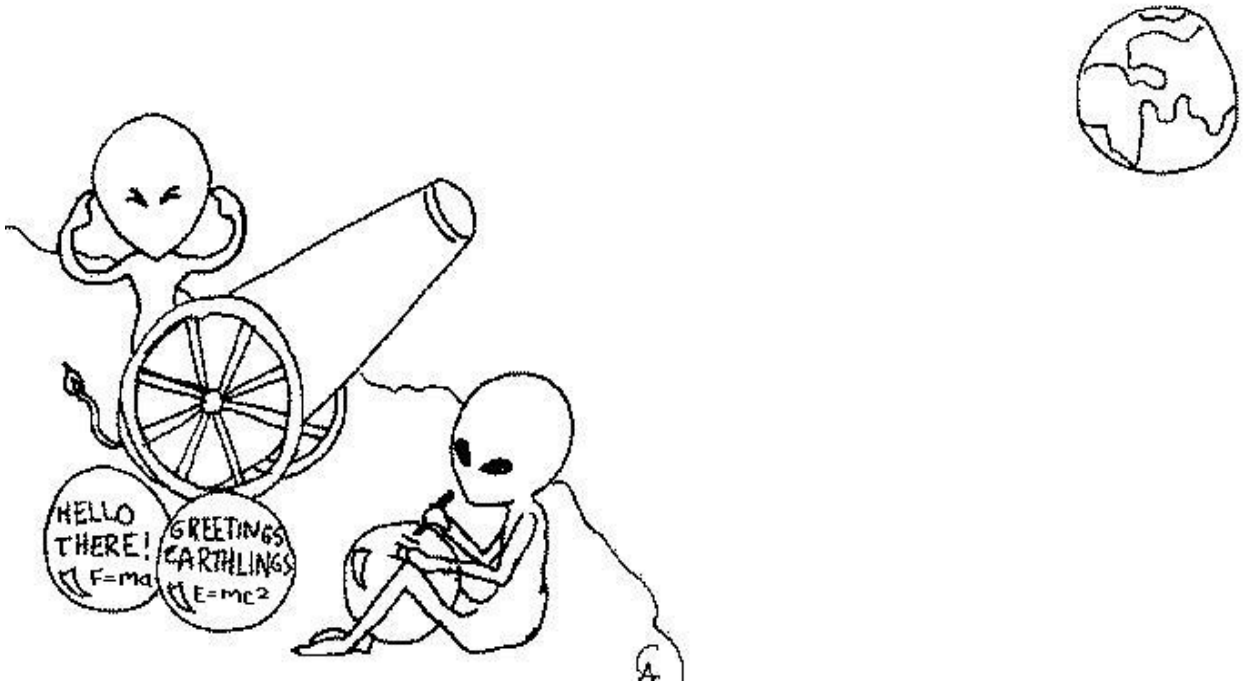
CONCLUSION

IF: energy important & delay tolerable
THEN: inscribed matter messaging is efficient

- Terrestrial
  - FedEx, Netflix, Snail Mail (literally!)
- Chip-to-chip or mote-to-mote
  - smart dust tossing inscribed dust
- Biological systems
  - construction/dispersal cost for messenger molecules

But perhaps most important ...

Great Conversation Starter!



AND...

RESEARCHER

Learn More

Nature 431, pp.47–49, September 2, 2004

Web Site: http://www.winlab.rutgers.edu/∼crose/cgi-bin/cosmicP.html