14 - THE DRAKE EQUATION (CONTINUED) AND INTERSTELLAR COMMUNICATION

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THE DRAKE EQUATION

This equation is used to estimate the number of “technological” civilizations in the Milky Way galaxy.

– We define a “technological” civilization as one that is capable of (and interested in) engaging in interstellar communications with other civilizations.

– Note: We are only making this estimate for our galaxy, but the number should be about the same for any similar spiral galaxy.

This is the number of civilizations that could be sending out radio (or other) signals that we might be able to receive.
DRAKE EQUATION

EXTREME OPTIMISTIC CASE

(Use optimistic values of all factors except L)

\[ N = 400 \text{ billion} \times 0.1 \times 2 \times 1 \times 1 \times 1 \times \frac{L}{10 \text{ billion}} \]

RESULT: \( N = 8L \)

Now look at different values of L:

IF \( L = 100 \) YEARS (pessimistic case for L),
THEN \( N = 800 \)

IF \( L = 10 \) BILLION YRS (optimistic case for L),
THEN \( N = 80 \) BILLION
DRAKE EQUATION

MY BEST ESTIMATE

\[ N = 400 \text{ billion} \times 0.05 \times 0.5 \times 1 \times 0.01 \times 0.5 \times \frac{L}{10 \text{ billion}} \]

RESULT:  \[ N = 0.005 \quad L = \frac{L}{200} \]

Now look at different values of \( L \):

IF \( L = 100 \text{ YEARS} \) (pessimistic case for \( L \)),
THEN \( N = 0.5 \)

IF \( L = 10 \text{ BILLION YRS} \) (optimistic case for \( L \)),
THEN \( N = 50 \text{ MILLION} \)
DRAKE EQUATION

EXTREME PESSIMISTIC CASE

(Use pessimistic values of all factors except L)

\[ N = 400 \text{ billion} \times 0.001 \times 0.1 \times 0.005 \times 0.001 \times 0.01 \times \frac{L}{10 \text{ billion}} \]

RESULT: \( N = 0.0000000002 \) \( L = 2 \times 10^{-10} \) \( L = L/5,000,000,000 \)

Now look at different values of L:

IF \( L = 100 \) YEARS (pessimistic case for L),
THEN \( N = 0.000000002 \)

IF \( L = 10 \) BILLION YRS (optimistic case for L),
THEN \( N = 2 \)
DRAKE EQUATION

WE KNOW THAT N MUST BE AT LEAST 1 BECAUSE WE EXIST!

THEREFORE:

IF THE EXTREME PESSIMISTIC CASE IS CORRECT (N = L / 5,000,000,000),
WE WOULD CONCLUDE THAT L > 5 BILLION YEARS.

THIS WOULD MEAN THAT CIVILIZATIONS ARE LONG-LIVED!
DRAKE EQUATION

WE KNOW THAT N MUST BE AT LEAST 1 BECAUSE WE EXIST!

THEREFORE:

IF THE EXTREME OPTIMISTIC CASE IS CORRECT (N = 8L),
WE CONCLUDE THAT L > 1/8 YEAR.

BUT WE ALREADY KNOW THIS!

(WE’VE HAD THE RELEVANT TECHNOLOGY FOR ABOUT 50 YEARS SO FAR.)
WE KNOW THAT N MUST BE AT LEAST 1 
BECAUSE WE EXIST!

THEREFORE:

IF MY BEST ESTIMATE IS CORRECT 
(N = 0.005 L),

WE CONCLUDE THAT L > 200 YEARS.
CONCLUSIONS BASED ON THE FACT THAT WE EXIST

- EITHER N = L IS VERY ROUGHLY CORRECT (TO WITHIN A FACTOR OF A FEW HUNDRED OR A FEW THOUSAND), AS IN THE EXTREMELY OPTIMISTIC CASE OR MY BEST ESTIMATE

OR

2. IF THE EXTREMELY PESSIMISTIC VALUES OF VARIOUS FACTORS ARE CLOSE TO CORRECT, THEN L MUST BE VERY LARGE
BUT WE SUSPECT FROM HUMAN EXPERIENCE THAT L COULD EASILY BE SMALL! (MORE ON THIS LATER)

THEREFORE WE CAN PROBABLY EXCLUDE THE EXTREMELY PESSIMISTIC CASE.

REALITY IS PROBABLY CLOSER TO THE OPTIMISTIC CASE (N ~ L) OR TO MY BEST ESTIMATE (N ~ L/200).
DRAKE EQUATION

N = # OF CIVILIZATIONS IN MW GALAXY CAPABLE OF INTERSTELLAR COMMUNICATION

L = AVERAGE LIFETIME OF SUCH A CIVILIZATION IN YEARS

RESULT: N \sim L

VERY ROUGHLY,

(TO WITHIN A FACTOR OF A FEW 100 OR FEW 1000)

BUT HOW LARGE IS L??

(BIGGEST SOURCE OF UNCERTAINTY)
DRAKE EQUATION

We will examine factors that affect L (the average lifetime of a “technological” civilization) later.

For now, let's examine how the value of L (and therefore N, the number of “technological” civilizations) affects the possibility of interstellar communication.

- The more civilizations there are, the closer together they'll be, on the average.
- The distance between civilizations determines how long it takes for messages to pass back and forth.
- Messages can't travel faster than the speed of light (one light year per year).
MILKY WAY GALAXY

N=1

* THIS IS US
MILKY WAY GALAXY

DISTRIBUTION OF CIVILIZATIONS

N=10

THIS IS US

WHY ISN’T THIS REALISTIC?
MILKY WAY GALAXY

DISTRIBUTION OF CIVILIZATIONS

N=10

RANDOM DISTRIBUTION, MORE REALISTIC

THIS IS US
MILKY WAY GALAXY

DISTRIBUTION OF CIVILIZATIONS

HOW HAVE THE DISTANCES BETWEEN CIVILIZATIONS CHANGED FROM N=10?
MILKY WAY GALAXY

DISTRIBUTION OF CIVILIZATIONS

THE LARGER THE NUMBER OF CIVILIZATIONS,

THE SMALLER THE AVERAGE DISTANCE BETWEEN THEM,

THE MORE FEASIBLE INTERSTELLAR COMMUNICATION BECOMES.
## Abundance of Life in the Galaxy (Assuming N = L)

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<th>Case</th>
<th>L (Years)</th>
<th>N (Years)</th>
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<tr>
<td>Scarce</td>
<td>2 million</td>
<td>2 million</td>
</tr>
<tr>
<td>Rare</td>
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<table>
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<tr>
<th>Case</th>
<th>Average Distance</th>
<th>Number of 2-Way Conversations</th>
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<tr>
<td>Rare</td>
<td>1,000 LY</td>
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**Number of Conversations:** The number possible within time L, based on the assumption that signals travel back and forth at the speed of light.
SOLVING THE DRAKE EQUATION

“ONCE SETI FINDS THE FIRST ONE, IT’S JUST STATISTICS.”

PHILLIP MORRISON

SETI = SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE
(METHODS TO BE DISCUSSED NEXT TIME)

WHAT DOES THIS STATEMENT MEAN?

ONCE WE FIND THE FIRST EXTRATERRESTRIAL CIVILIZATION, WE'LL KNOW AN APPROXIMATE VALUE FOR N, AND THUS WE'LL HAVE A BETTER ESTIMATE OF L ALSO. LET'S SEE HOW THIS WORKS.
SOLVING THE DRAKE EQUATION

SUPPOSE SETI FINDS A SIGNAL, AND ASTRONOMERS DETERMINE THE DISTANCE TO THAT CIVILIZATION TO BE 100 LY.

ASSUMING THIS DISTANCE IS ALSO THE AVERAGE DISTANCE BETWEEN NEAREST-NEIGHBOR CIVILIZATIONS (STATISTICALLY A GOOD ASSUMPTION),

THEN N = 2 MILLION.
SOLVING THE DRAKE EQUATION

WITH $N = 2 \text{ MILLION}$:

IF $N \sim 10 \text{ L}$, THEN $L \sim 200,000 \text{ YEARS}$, 
TIME FOR 100 ROUND-TRIP CONVERSATIONS.

IF $N \sim 0.001 \text{ L}$, THEN $L \sim 2 \text{ BILLION YEARS}$, TIME FOR 10 MILLION ROUND-TRIP CONVERSATIONS.

THEN WE CAN FEEL CONFIDENT THAT THERE ARE A LOT OF LONG-LIVED CIVILIZATIONS, AND THAT COMMUNICATION WITH THEM IS FEASIBLE.
WE CAN ALSO FEEL CONFIDENT THAT HUMAN CIVILIZATION IS LIKELY TO SURVIVE FOR A LONG TIME.
SOLVING THE DRAKE EQUATION

WHAT IF SETI DOES NOT FIND ANY EVIDENCE OF EXTRATERRESTRIAL CIVILIZATIONS WITHIN 1,000 LY? THEN N < 2000.

IF N ~ 10 L, THEN L < 200 YEARS, NO TIME FOR ANY CONVERSATIONS.

IF N ~ 0.001 L, THEN L < 2,000,000 YEARS, TIME FOR <1000 ROUND TRIP CONVERSATIONS.

THEN DEPENDING ON WHAT WE ASSUME ABOUT THE DRAKE EQUATION, CIVILIZATIONS MAY BE SO FEW AND FAR BETWEEN THAT COMMUNICATION WITH THEM MAY NOT BE FEASIBLE.

WE ALSO MAY FEEL MORE PESSIMISTIC ABOUT THE LIKELY LIFETIME OF HUMAN CIVILIZATION.
HOW TO SEARCH FOR LIFE IN OTHER SOLAR SYSTEMS: TRAVEL OR COMMUNICATION?

- INSTEAD OF SPACESHIPS, USE PHOTONS

- ADVANTAGES OF PHOTONS (LIGHT):
  - TRAVEL AT SPEED $c$ (FASTER THAN ANY SHIP)
  - REQUIRE LESS ENERGY THAN SPACESHIPS
  - CHEAPER
  - CAN CARRY JUST AS MUCH INFORMATION
  - RISK OF BIOLOGICAL CONTAMINATION IS ELIMINATED
ELECTROMAGNETIC SPECTRUM

SPEED OF LIGHT
$c = 300,000 \text{ km/s}$
$c = 1 \text{ light year/year}$

FREQUENCY = NUMBER OF WAVES PER SECOND

1 Hertz = 1 wave per second
1 kHz = 1,000 Hz
1 MHz = 1,000 kHz = 1,000,000 Hz

SPEED = FREQUENCY \times WAVELENGTH
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<th>FREQUENCY</th>
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<tr>
<td>GAMMA RAYS</td>
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</tr>
<tr>
<td>INFRARED</td>
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</tr>
<tr>
<td>MICROWAVE</td>
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<td>1000 MHz</td>
</tr>
<tr>
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<td>100 MHz</td>
</tr>
<tr>
<td>AM RADIO</td>
<td>100 m</td>
<td>1000 kHz</td>
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RADIO COMMUNICATION

ADVANTAGES OF RADIO WAVES:

- NOT AFFECTED BY INTERSTELLAR DUST
- LOW ENERGY COSTS
- LOW NOISE BACKGROUND
- HIGH INFORMATION CAPACITY
- TRAVEL AT THE SPEED OF LIGHT (LIKE ALL FORMS OF ELECTROMAGNETIC RADIATION)
TYPES OF SIGNALS

- DELIBERATE SIGNALS: Sent in hopes that another civilization will receive them.

- ACCIDENTAL SIGNALS: Used by the civilization for other purposes, but escape into space inadvertently.

WHAT HAVE WE SENT?
- So far, we have sent only one short (3 minute duration) deliberate signal.
- However, we are sending out lots of accidental signals.

WHAT ARE WE TRYING TO RECEIVE?
- SETI = Search for Extraterrestrial Intelligence (ongoing).
- Searching for either deliberate or accidental signals.
ACCIDENTAL SIGNALS THAT WE ARE SENDING

- TV AND FM RADIO TRANSMISSIONS HAVE BEEN LEAVING EARTH SINCE ABOUT 1940.
- THEY HAVE MADE IT A LITTLE OVER 60 LY IN THAT TIME (REACHED 2500 STARS).
- ANYONE WITH OUR LEVEL OF DETECTION TECHNOLOGY COULD DETECT US IF THEY ARE WITHIN 30 TO 40 LY.
- DOPPLER SHIFTS IN SIGNALS WOULD RESULT FROM THE EARTH’S ROTATION AND ITS ORBIT AROUND SUN.
- SIGNAL STRENGTH WOULD ALSO VARY AS VARIOUS PARTS OF THE EARTH ROTATE IN AND OUT OF VIEW OF THE OBSERVER.
- WE HAVEN’T DETECTED ANYTHING LIKE THIS FROM NEARBY STARS.
Fig. 20-4  The Earth’s ionosphere reflects most of the AM (long wavelength) radio photons that reach it, but lets FM, television, and microwave (e.g., radar) photons pass through it unimpeded.
BUT WILL WE CONTINUE TO BROADCAST MUCH LONGER?

- A “BROADCAST” SENDS OUT A SIGNAL IN ALL DIRECTIONS (ALTHOUGH IT IS NOT EQUALLY STRONG IN ALL DIRECTIONS).
- CABLE AND OTHER FORMS OF DIRECTED DELIVERY MAY BE REPLACING BROADCASTS.
- IF MOST CIVILIZATIONS PROCEED THIS WAY, THE FRACTION OF THE CIVILIZATION’S LIFETIME SPENT BROADCASTING MAY BE RELATIVELY SHORT.
DELIBERATE SIGNALS

RADIO WAVES ARE BEST (FOR REASONS GIVEN EARLIER).

BUT WHAT FREQUENCY DO WE LISTEN AND/OR TRANSMIT AT?

(RADIO WAVES INCLUDE ALL FREQUENCIES BELOW 300 MHz OR ALL WAVELENGTHS LARGER THAN 1 METER).

ANSWER: FREQUENCIES BETWEEN A FEW HUNDRED MHz AND A FEW THOUSAND MHz ARE BEST

WHY?
SELBERATE SIGNALS

AT FREQUENCIES BELOW A FEW HUNDRED MHz, THERE ARE RADIO WAVES EMITTED BY ELECTRONS IN STRONG MAGNETIC FIELDS (PRODUCED BY A VARIETY OF ASTROPHYSICAL SOURCES). THESE PRODUCE A LOT OF “NOISE” THAT WOULD COMPETE WITH A SIGNAL

FREQUENCIES ABOVE A FEW THOUSAND MHz ARE ABSORBED BY OXYGEN AND WATER IN EARTH’S ATMOSPHERE (AND ALIENS' ATMOSPHERE, IF IT IS SIMILAR)
DELIBERATE SIGNALS

SO RADIO WAVES WITH FREQUENCIES FROM A FEW HUNDRED MHz TO A FEW THOUSAND MHz ARE BEST. (THIS IS SLIGHTLY ABOVE THE FREQUENCY RANGE USED BY TV AND FM RADIO.)

BUT THIS IS A LARGE RANGE, AND WE COULD SPEND A LONG TIME SEARCHING AT VARIOUS FREQUENCIES WITHIN THIS RANGE.

IS THERE ANY “SPECIAL” FREQUENCY WITHIN THIS RANGE THAT MIGHT SEEM LIKE A NATURAL CHOICE?

YES!
DELIBERATE SIGNALS

“SPIN FLIP” TRANSITION IN THE HYDROGEN ATOM: FREQUENCY = 1420 MHz, WAVELENGTH = 21 cm.

BUT H ATOMS THEMSELVES RADIATE AT THIS FREQUENCY, PROVIDING BACKGROUND “NOISE” FROM 1419 TO 1421 MHz (SPREAD BECAUSE OF DOPPLER EFFECT) SO MAYBE SOMEWHERE NEAR (BUT NOT EXACTLY) 1420 MHz IS BEST.

ANOTHER “LANDMARK”: 1721 MHz TRANSITION IN OH MOLECULE.

ANY “TECHNOLOGICAL” CIVILIZATION WOULD KNOW ABOUT THESE FREQUENCIES.

THE “WATER HOLE” IS THE FREQUENCY RANGE BETWEEN 1420 AND 1721 MHz.
THE WATER HOLE

RANGE OF FREQUENCIES WITH MINIMUM BACKGROUND RADIO NOISE

FREQUENCY RANGE FROM 1420 TO 1721 MHz
1420 MHz IS AN EMISSION LINE OF H ATOM
1721 MHz IS AN EMISSION OF OH MOLECULE
RANGE IN FREQUENCY = 300 MHz = 300,000,000 Hz

CHOICE OF NAME:
H + OH $\rightarrow$ H₂O (WATER)
MINIMUM LEVEL OF NOISE $\rightarrow$ “HOLE”
EVOKE IMAGE OF A GATHERING PLACE FOR ANIMALS, SUGGESTING THAT MESSAGES FROM CIVILIZATIONS MAY BE GATHERED IN THIS FREQUENCY RANGE
INTERSTELLAR RADIO AND TELEVISION MESSAGES

- RECEIVED SIGNAL LEVEL
- FREQUENCY (MHz)

- The "Water Hole"
- Absorption by Earth's atmosphere
- Galactic noise
- OH lines
- H line
- Areceibo message to M13
- 3K background
- Total background noise

Graph showing signal levels and frequencies.
SEARCHING THE WATER HOLE

A CHANNEL IS A SMALL RANGE IN FREQUENCY (BANDWIDTH) OVER WHICH A SIGNAL IS TRANSMITTED OR RECEIVED, TYPICALLY ABOUT 0.5 Hz.

SETI MUST SEARCH A RADIO “DIAL” OF 300,000,000 Hz:

\[
\text{300,000,000 Hz} \\
\text{0.5 Hz/CHANNEL}
\]

GIVES 600 MILLION CHANNELS IN THE WATER HOLE!
A LOT OF CHANNELS TO SEARCH!

FORTUNATELY, MODERN RECEIVERS (MULTI-CHANNEL ANALYZERS) CAN SEARCH SEVERAL HUNDRED MILLION CHANNELS SIMULTANEOUSLY!
SEARCH STRATEGIES

TARGETED SEARCH

POINT RADIO TELESCOPE IN THE DIRECTION OF SUITABLE STARS AND LOOK FOR A SIGNAL.

SKY SURVEY

SEARCH WHEREVER THE RADIO TELESCOPE (WHILE IN USE FOR OTHER PURPOSES) HAPPENS TO BE POINTING, E.G. PROJECT SERENDIP.

NOTE: ARECIBO RADIO TELESCOPE IS NON-POINTABLE. AS THE EARTH ROTATES, SEARCH SKY IN FRONT OF TELESCOPE.
HISTORY OF SETI

1959: Water hole suggested as best frequency range to search, by Giuseppi Cocconi and Philip Morrison

1960: Project Ozma, Frank Drake searched Tau Ceti & Epsilon Eridani (nearby suitable stars)

1961: Drake Equation & first meeting about SETI, ten attendees including Sagan, Drake, & Morrison

1960’s: Many all-sky surveys carried out in Soviet Union

1973-82: Horowitz, targeted ~400 Stars

1974: Signal (lasting 3 minutes) sent by Arecibo radio telescope towards globular cluster M13

1983-85: Sentinel & Horowitz, all-sky survey
1985-92: META, 8 million channels, funded by Planetary Society

1985-present: SERENDIP including SETI@home (http://seti.berkeley.edu), “piggybacks” on radio telescopes that are performing other observations

1988: NASA funds a SETI Project

1990: Observations begin

1993: NASA forced to kill SETI Project

1994-present: Project Phoenix, targeted search carried out by SETI Institute, funded by private donations

1995-present: Project BETA funded by Planetary Society. This search uses a multi-channel analyzer that can search 250 million channels simultaneously. The entire “water hole” frequency range can be searched in 16 seconds per star.
ARECIBO RADIO TELESCOPE
PLEASE DEPOSIT $3,482,344.44 FOR THE FIRST THREE MINUTES...
LASERS FOR COMMUNICATIONS?

- A LASER BEAM IS TIGHTLY COLLIMATED (DOESN’T SPREAD OUT) – ENERGY CONCENTRATED IN A SINGLE DIRECTION.

- ENERGY ALSO CONCENTRATED AT A SINGLE WAVELENGTH – CAN OUTSHINE A STAR AT THAT WAVELENGTH.

- VISIBLE LIGHT (LASER) EASIER TO USE THAN RADIO WAVES OR MICROWAVES (MASER).

- MAY BE PREFERABLE TO RADIO COMMUNICATIONS IF DESTINATION IS KNOWN.

- SINCE SIGNAL IS TIGHTLY BEAMED, WE ARE LESS LIKELY TO INTERCEPT A SIGNAL ACCIDENTALLY.
WHAT WILL A SIGNAL CONSIST OF?

- A SIGNAL THAT DOESN’T CHANGE WITH TIME CARRIES NO INFORMATION.

- INFORMATION CAN BE CARRIED BY CHANGING THE INTENSITY (AM) OR WAVELENGTH (FM) OF SIGNAL WITH TIME.

- BUT WHAT CONTENT DO WE WANT TO PUT INTO THE MESSAGE, AND HOW DO WE PUT IT THERE? HOW CAN WE INCREASE THE LIFELIHOOD THAT THE ALIENS WILL UNDERSTAND WHAT WE ARE TRYING TO SAY?

- REMEMBER THAT THE ALIENS WON’T KNOW OR USE ANY HUMAN LANGUAGES.
WHAT WILL A SIGNAL CONSIST OF?
- What content do we want to put into the message, and how do we put it there?
- Doesn't make sense to use any human language?
- Pictures?
  - How do transmit a picture using radio waves or lasers?
- Mathematics?
  - Mathematics provides a universal language that any technological civilization will understand.
  - We can use math to transmit a picture.
  - But what kind of mathematics?
COUNTING IN BINARY AND DECIMAL

0+0=0        1+0=1        1+1=2        2+1=3        3+1=4
4+1=5        5+1=6        6+1=7        7+1=8        8+1=9

NOTICE THAT A NEW SYMBOL IS CREATED FOR EACH NEW NUMBER.

UNTIL... 9+1=10, WHICH IS “NINE PLUS ONE IS TEN, BUT WRITE ZERO AND CARRY THE ONE.” A NEW SYMBOL IS NOT CREATED TO REPRESENT THE NUMBER TEN. IN THE DECIMAL SYSTEM, THERE ARE ONLY TEN DIFFERENT SYMBOLS (0, 1, 2, 3, 4, 5, 6, 7, 8, AND 9) USED.

IN BINARY, THERE ARE ONLY TWO SYMBOLS (0 AND 1):

0 + 0 = 0        1 + 0 = 1        1 + 1 = 10

(10 = THE NUMBER TWO WRITTEN IN BINARY)

10 + 1 = 11 (THREE)        11 + 1 = 100 (FOUR)…
<table>
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<td>8</td>
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DECIMAL vs. BINARY

- IN DECIMAL, AN EXAMPLE IS 7201 =
  \[(7 \times 1000) + (2 \times 100) + (0 \times 10) + (1) = (7 \times 10^3) + (2 \times 10^2) + (0 \times 10) + (1 \times 1)\]

- IN BINARY, AN EXAMPLE IS 1011 =
  \[(1 \times 8) + (0 \times 4) + (1 \times 2) + (1) = (1 \times 2^3) + (0 \times 2^2) + (1 \times 2) + (1 \times 1)\]
  (This number would be written as 11 in decimal)
BINARY NUMBERS

- SIMPLEST SYSTEM – ONLY TWO SYMBOLS (0 AND 1) NEEDED
- EACH SYMBOL (0 OR 1) IS A BIT
- USED BY MOST COMPUTERS

A MESSAGE CONSISTING OF A SEQUENCE OF BITS COULD BE ENCODED IN SEVERAL OBVIOUS WAYS:

- A PULSE COULD BE A “1” AND A GAP (NO SIGNAL) COULD BE A “0” (OR VICE VERSA)
- A LONGER-DURATION PULSE COULD BE A “1” AND A SHORTER-DURATION PULSE COULD BE A “0” (OR VICE VERSA)
BINARY NUMBERS

- MESSAGE CAN ENCODE A PICTURE – LET 0 BE A WHITE DOT AND 1 BE A BLACK DOT (OR VICE VERSA)
- THE DOTS MUST BE ARRANGED TO MAKE A PICTURE
- IF WE START STRINGING TOGETHER THE DOTS IN ONE LONG ROW (OR COLUMN), IT WON'T LOOK LIKE A PICTURE
- INSTEAD, WE MUST STRING TOGETHER DOTS UNTIL WE REACH THE END OF A ROW (OR COLUMN), THEN START ANOTHER ROW (OR COLUMN)
- HOW DO WE KNOW WHEN WE REACH THE END OF A ROW (OR COLUMN)?
**BINARY NUMBERS**

- MUST ARRANGE BITS INTO ROWS AND COLUMNS IN AN UNAMBIGUOUS WAY
  - IF A MESSAGE CONTAINS 1200 BITS, THE DOTS COULD BE ARRANGED IN:
    - 30 ROWS, 40 COLUMNS (OR VICE VERSA)
    - 50 ROWS, 24 COLUMNS (OR VICE VERSA)
    - 60 ROWS, 20 COLUMNS (OR VICE VERSA)
    - 120 ROWS, 10 COLUMNS (OR VICE VERSA)
  - WE'D HAVE TO CHECK ALL THESE POSSIBILITIES TO SEE IF ANY OF THEM RESULTED IN SOMETHING THAT LOOKED LIKE A PICTURE

- CHOOSE TOTAL NUMBER OF BITS IN THE MESSAGE TO BE THE PRODUCT OF TWO PRIME NUMBERS
  - FOR EXAMPLE, 551 = 19 x 29
  - BUT IS THIS 19 ROWS AND 29 COLUMNS, OR 29 ROWS AND 19 COLUMNS?
WHAT COULD IMPROVE THIS MESSAGE?

- MORE INFORMATION - INCREASE THE NUMBER OF BITS.
  - WOULD MAKE THE PICTURE MORE “NATURAL” - OBJECTS
    WOULD BE MORE GENTLY CURVED RATHER THAN POINTY
  - WOULD SPREAD OBJECTS FURTHER APART, MAKING IT MORE
    OBVIOUS WHAT EACH ONE IS SUPPOSED TO BE

- COULD USE MULTIPLE PICTURES TO INDICATE MOTION
  (WITH A LONGER GAP BETWEEN “FRAMES”).

- ONCE SOME INFORMATION IS EXCHANGED, WE COULD
  PROBABLY EVENTUALLY AGREE WITH THEM ON OTHER
  WAYS TO ENCODE INFORMATION MORE EFFICIENTLY.
FIRST CONTACT

ANY EVIDENCE, WHETHER THROUGH RADIO COMMUNICATION OR DIRECT ENCOUNTER, THAT EXTRATERRESTRIAL INTELLIGENCE (ETI) EXISTS

HOWEVER, KEEP IN MIND SAGAN’S CAUTION:

“AN EXTRAORDINARY CLAIM REQUIRES EXTRAORDINARY EVIDENCE”
(Sagan, date unknown)
FIRST CONTACT

U.N. DECLARATION OF PRINCIPLES

1. **BE CERTAIN THAT THE SIGNAL CANNOT BE EXPLAINED BY NATURAL OR TERRESTRIAL PHENOMENA.**

2. **INFORM OTHER RESEARCHERS OF THE DISCOVERY AND WAIT FOR THEIR CONFIRMATION.**

3. **MAKE AN ANNOUNCEMENT TO THE INTERNATIONAL SCIENTIFIC COMMUNITY.**

4. **MAKE ALL DATA AVAILABLE TO SCIENTIFIC COMMUNITY.**

5. **CONTINUE TO OBSERVE AND RECORD EVERYTHING.**

6. **OFFICIALLY PROTECT THE FREQUENCIES. STOP USING THEM FOR ANYTHING ELSE.**

7. **THE PUBLIC SHOULD BE INFORMED THROUGH RESPONSIBLE SCIENTIFIC ORGANIZATIONS.**

8. **DO NOT RESPOND UNTIL WE DECIDE WHAT TO DO. THE DECISION SHOULD BE MADE BY A DIVERSE GROUP OF SCIENTISTS, GOVERNMENT OFFICIALS, AND ORDINARY PEOPLE FROM MANY PARTS OF THE WORLD.**
RESPONSE TO FIRST CONTACT?

- PANIC?
  - FEAR OF INVASION OR WAR
  - INTERSTELLAR INVASION OR WAR IS PROBABLY NOT FEASIBLE GIVEN THE DIFFICULTIES OF INTERSTELLAR SPACE TRAVEL (NEXT TIME)

- JOY?
  - KNOWLEDGE THAT WE ARE NOT ALONE
  - PERHAPS WE CAN LEARN SOMETHING USEFUL FROM THE ALIENS

- SIGNIFICANT EFFECTS ON RELIGION, PHILOSOPHY, ETC.?
  - AS PEOPLE RE-EVALUATE THE HUMAN SPECIES' PLACE IN THE UNIVERSE