

AT PRESENT AT LEAST SIX GROUPS OF RADIO ASTRONOMERS INVOLVED IN DIFFERENT EXPERIMENTS AIMED AT DETECTING SIGNALS OF INTELLIGENT ORIGIN. AHB INVOLVED IN TWO OF THESE. WHY TRY TO DETECT RADIO SIGNALS FROM LIFE BEYOND EARTH ?

TALK IN TWO MAIN PARTS:

1) GIVE BACKGROUND TO THINKING THAT LIFE MIGHT BE WIDESPREAD IN THE UNIVERSE. NO PROOFS, NOT EVEN STATISTICS OR PROBABILITIES. WE ARE IN THE DARK STILL ON SOME CRUCIAL POINTS AND THAT IS WHY I FAVOUR EXPERIMENT.

2) SOME THINKING ABOUT HOW TO EXPERIMENT IN THIS AREA, AND DESCRIPTION OF WHAT'S GOING ON.

FIRST \* WHAT IS LIFE ?

OBVIOUSLY GOOD FOR SEVERAL PH.D. THESES IN BIOLOGY, AND MAYBE STILL A NOBEL PRIZE OR TWO, SO I'M GOING TO TOUCH LIGHTLY ON A FEW SALIENT POINTS RATHER THAN TRY TO DIG INTO DEPTHS !

FAMOUS BUDDHIST MONK ONCE CHALLENGED TO DEMONSTRATE A MIRACLE BY RIVAL WHOSE LEADER HAD ALLEGEDLY PERFORMED MANY WONDERS. HE REPLIED "MY MIRACLE IS THAT WHEN I FEEL HUNGRY I EAT AND WHEN I FEEL THIRSTY I DRINK".

THIS IS THE SECRET OF LIFE.

AROUND US AND IN US A SMALL FRACTION OF ALL EARTHLY MATTER CHALLENGES THE GENERAL TREND TOWARDS CHAOS AND DISORDER IN UNIVERSE. INANIMATE MATTER BECOMES DISORGANISED. OLD BUILDINGS BECOME HEAPS OF RUBBLE, NOT THE REVERSE. SHINY CARS BECOME RUSTING HULKS IN THE WRECKER'S YARD, NOT THE REVERSE. SECOND LAW OF THERMODYNAMICS SAYS THE ENTROPY KEEPS INCREASING, THINGS GET WORSE BEFORE THEY GET STILL WORSE. BUT LIVING ORGANISMS ARE HIGHLY STRUCTURED, ORGANISED. THE STRUCTURE ITSELF DOES NOT GUARANTEE LIFE - COMPLEXITY IS NOT LIFE ALTHOUGH LIFE IS COMPLEX. A DEAD WHALE IS DEAD, A LIVE VIRUS LIVES.

LIVING THINGS KEEP THEIR ENTROPY LOW, THEIR ORGANISATION HIGH, BY INTERACTING WITH THEIR ENVIRONMENT IN PARTICULAR WAY. SOURCE OF ORDERED ENERGY IN ENVIRONMENT (FOOD, SUNLIGHT) BORROWED FROM. ENERGY MANIPULATED TO INCREASE, REPAIR, OR REPRODUCE STRUCTURAL ORDER OF ORGANISM, THEN RETURNED TO ENVIRONMENT DISORDERED (WASTE PRODUCTS AND HEAT) - HEAT IS MORE DISORDERED THAN SUNLIGHT BECAUSE MORE PHOTONS PER ENERGY UNIT. LIVING SYSTEMS KEEP THEIR ENTROPY LOW (ORDER INTACT) AT EXPENSE OF INCREASING RATE OF DISORDERING OF THEIR ENVIRONMENT.

LIFE NEEDS A MECHANISM AND AN ENVIRONMENT CAPABLE OF SUPPLYING ORDERED ENERGY AND ACCEPTING DISORDERED ENERGY. CAN PRODUCE DEATH BY CUTTING OFF THE ENERGY SOURCE, DAMAGING THE MECHANISM, OR POLLUTING THE ENVIRONMENT WITH WASTE.

TO APPRAISE WHETHER LIFE IS LIKELY TO EXIST BEYOND EARTH, WE HAVE TO ASK IF ENVIRONMENTS EXIST, AND IF MECHANISM CAN BE ~~XXXXXXXXXX~~ ESTABLISHED. OF COURSE, THE ENVIRONMENT MIGHT BRING ABOUT THE MECHANISM, BUT WE'LL DISCUSS THAT IN A MOMENT.

SINCE 17th CENTURY ASTRONOMY HAS TAUGHT US THAT ABOVE ALL THE UNIVERSE IS FULL OF 'ENVIRONMENTS'. NO LONGER CAN WE BELIEVE THAT THE AERTH IS THE ENVIRONMENT, WITH HEAVENS A PERIPHERAL SPHERE. WE ARE ON ONE PLANET OF AN UNDISTINGUISHED STAR IN A RUN\*OF\*THE\*UNIVERSE SPIRAL GALAXY.

BUT NOT ENOUGH TO JUST SAY \* UNIVERSE IS VAST AND FULL OF ALL KINDS OF MARVELLOUS LOW\*ENTROPY ENERGY FLOWS - EVEN IF EVERY SUNLIKE STAR HAD PLANETS, WHICH WE DEFINITELY DO NOT KNOW, AND EVERY PLANET WAS EARTHLIKE, WHICH WE DEFINITELY KNOW IS WRONG, WE COULD NOT BE SURE THAT THE HUGENESS OF THE UNIVERSE GURANTEED EXISTENCE OF LIFE AS WE KNOW IT. BECAUSE EVEN A HUGE NUMBER OF CHANCES DO NOT GUARANTEE THE OCCURENCE OF SOMETHING OF INFINITESIMALLY SMALL PROBABILITY. WHAT WE REALLY HAVE TO ASK IS : HOW IMPROBABLE IS LIFE AS WE KNOW IT, HOW MUCH OF A FREAK IS THE ~~XXX~~ GOOD MATCH BETWEEN THIS ENVIRONMENT AND THE LIFE IN IT ? IF LIFE AS WE KNOW IT IS SOME INCREDIBLE QUIRK DEPENDING ON SOME RARE IMPLAUSIBILITY, THEN EVEN THE NUMBER OF STARS IN THE NUMBER OF GALAXIES MIGHT NOT BE ENOUGH TO ENSURE THAT IT HAPPENED ANYWHERE ELSE.

MIGHT TRY FOR A CLUE BY SEEING WHAT RANGE OF ENVIRONMENTS LIFE EVEN AS WE KNOW IT TURNS UP IN.

- SLIDES - NUCLEAR REACTOR
- BREWERS VAT
- DESERT CACTUS
- DESICCATED VIRUS
- VIRUSES ATTACK BACTERIUM
- ARCTIC LUPIN

ALSO IN NEAR\*BOILING WATERS OF GEYSERS, SIMULATED MARS JARS 350,000 PLANT AND 1,200,000 ANIMAL SPECIES NOW.

FANTASTIC, BUT CAN'T JUMP TOO FAR TO A CONCLUSION. THERE'S A CATCH. ALL THIS VARIETY IN ENVIRONMENTAL ADAPTION DOES NOT IMPLY GREAT VARIETY IN MECHANISM. IN FACT, ALL EARTH LIFE FROM ROSES TO ROBINS, FROM MICROBES TO MINNOWS, HAS CLOSELY SAME CHEMISTRY.

SLIDE \* CHEMICAL BUILDING BLOCKS.

20 AMINO ACIDS, 5 NUCLEOTIDE BASES, 2 SUGARS, 1 PHOSPHATE ~~AND~~ ~~WATER~~ RUN MAJOR PART OF LIFE'S CHEMISTRY. THERE IS ONLY ONE KIND OF

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GIVEN THE ENVIRONMENT, DO WE GET THE LIFE ? THE INGREDIENTS ARE NOT THE CAKE, NOR DO THEY ENSURE THE LATER EXISTENCE OF THE CAKE.

QUESTION IS : HOW DID THE NUCLEOTIDE PATTERNS THAT ORGANISE ~~THE~~ LIFE AS WE KNOW IT FIRST APPEAR ?

TODAY LIFE ONLY APPEARS IN PRESENCE OF PRE\*EXISTING LIFE THAT CARRIES THE CRITICAL ORGANISING PATTERNS (THE GENETIC CODE, ETC.) HOW DID THESE PATTERNS FIRST APPEAR ? WE DO NOT SEE LIFE ORIGINATING AROUND US, AND INDEED CIRCUMSTANCES MAY HAVE CHANGED SO THAT IT CANNOT. TODAY'S ENVIRONMENT SEVERELY MODIFIED BY TODAY'S LIFE (OXYGEN IN ATMOSPHERE, NOT CO<sub>2</sub>, ETC.) AND MAY ACTUALLY BE UNSUITABLE FOR ORIGIN OF LIFE.

THEORY: RANDOM CHEMICAL ASSEMBLY. SIMPLE MOLECULES IN PRIMEVAL EARTH ENVIRONMENT BROKEN UP AND REASSEMBLED IN PRESENCE OF ENERGY SUPPLY (e.g. UV, LIGHTNING, LIGHT, HEAT)

SLIDE - MILLER'S EXPERIMENT.

EASY SYNTHESIS OF AMINO-ACIDS, CARBOHYDRATES. ENERGY SUPPLY NON-SPECIFIC PROVIDING CAN BREAK BONDS OF ATMOSPHERIC MOLECULES OCCASIONALLY, AND PROVIDING SHELTER PROVIDED FOR PRODUCTS (MUSTN'T BREAK THEM BACK UP). SIMULATE PASSAGE OF GEOLOGICAL TIME BY CONCENTRATING PRODUCTS, WASHING THEM, ETC. HAVE DEMONSTRATED PEPTISATION (LINKING OF AMINOACIDS INTO PROTEIN-LIKE CHAINS) AND COACERVATION (ORGANISATION OF PRODUCTS INTO CELL-LIKE SPHERES WITH BOUNDARY MEMBRANES). CONCLUDE THAT CHEMICAL INGREDIENTS OF LIFE COULD HAVE BEEN BUILT UP IN PRIMEVAL ENVIRONMENT BY RANDOM ASSEMBLY.

BUT (IMPORTANT !!) CAN'T PROVE IT DID HAPPEN THIS WAY

YET TO PROVE THE PATTERN-CODING ~~XXX~~ CAN HAPPEN THIS WAY. FASCINATING AREA: ONLY EVER NEED ONE SELF\*REPRODUCING MOLECULE, THE FIRST WILL DO THE REST. BILLION YEARS TO IT AND TEN SECONDS TO THE NEXT. Q. HOW COMPLEX DOES IT HAVE TO BE TO CODE AN ORGANISM ? MAYBE NOT AS COMPLEX AS TODAY'S CODING IS - SOL SPIEGELMAN SHOWED THAT FACED WITH TIME AND CHEMICAL BARRIERS TO REPLICATION, Q $\beta$  RNA VIRUS SHED PIECES OF ITSELF INESSENTIAL TO REPLICATION (TRANSFER FROM TUBE TO TUBE CONTAINING REPLICASE ENZYME, 'POISONING' ENVIRONMENT ETC.) SO MAYBE THE ORIGINAL STATISTICAL BARRIER IS NOT TOO FIERCE.

NO PROOF YET: OTHER MODELS (~~XXXX~~ TRANSPARANCY): DIVINE INTERVENTION, PANSPERMIA OF VARIOUS KINDS. NEED SIMULATION OF PRIMEVAL ENVIRONMENT TO PRODUCE SELF\*REPLICATING MOLECULE CAPABLE OF CODING AN ORGANISM. SLIDE: PROBLEMS WORTHY OF ATTACK.

AGAIN, TREND IS ENCOURAGING, BUT PROOF IS LACKING. WAIT TILL WE UNDERSTAND LIFE CHEMISTRY EVOLUTION, OR GO LOOK, SAYING WE DO NOT YET SEE THAT WE SHOULD BE UNIQUE (TRUE OF ANY CODE ORIGIN MODEL, INCL. God)

Slide  
- Moon  
Man

# Origin of the Genetic Code - Blueprint for Life

## Theoretical Models

### 1. Divine Intervention

Article of faith, not subject to verification by experimental science.

### 2. Random chemical assembly on Earth

Statistically implausible if coding as complex as in today's living matter. But implausible is not impossible and complexity may have evolved. Subject to experiment.

### 3. Various "panspermia" models

Arrival on Earth from elsewhere.

By meteorite

directed space capsule

extraterrestrial astronauts' contamination

Disadvantage: Transfers problem of origin to "Somewhere else" — theoretical cowardice?

Advantage: Possibly rare event need only happen once, then propagate.

SO LET'S DRAW UP A CONCLUSION. LIFE NEEDS AN ENVIRONMENT AND AN ENERGY-MANIPULATING AND STRUCTURING MECHANISM. WE DON'T KNOW HOW DIFFERENT THE MECHANISM COULD BE, SO WE CONSIDER OUR OWN PROTEIN\*WATER TYPE AS A SUBSET OF THE QUESTION.

ASTRONOMY SAYS LIKELY THAT PLANETS ARE THERE, BUT NO PROOF

CERTAIN THAT ELEMENTS ARE THERE

BIOCHEMISTRY SAYS CONCEIVABLE THAT MECHANISM EVOLVED FROM ENVIRONMENT SO WE KNOW OF NO DEFINITE OBSTACLE TO LIFE AS WE KNOW IT HAVING EVOLVED ON EARTHLIKE PLANETS OF 1/3 TO 1/2 OF ALL GALACTIC STARS HAVING RIGHT CHEMICAL COMPOSITION.

DEAL WITH TIME\*SCALE FOR EVOLUTION HERE. SLIDE: GEOLOGICAL CLOCKFACE FOSSIL RECORD TRACES BACK UNAMBIGUOUSLY TO 2 BILLION YEARS, CONTROVERSIALLY STILL FURTHER TO ABOUT 3 BILLION. AGAIN, DON'T KNOW HOW TYPICAL A 3-BILLION YEAR TIMESCALE WOULD BE, BUT SUPPOSE THAT IT IS:

STAR MUSTN'T LEAVE MAIN\*SEQUENCE IN THAT TIME, OTHERWISE PLANETARY ENVIRONMENT BECOMES UNSTABLE.

SLIDE: STAGES IN STELLAR EVOLUTION  
LIFETIME VERSUS SPECTRAL TYPE ]

BUT OTHER THINGS BEING EQUAL, LUMINOUS STARS HAVE BIGGER VOLUME OF SPACE HABITABLE TO ANY GIVEN ORGANISM (FREEZING-FRYING BOUNDARY)

SLIDE: HABITABLE ZONES

COMBINATION OF COMPETING PROBABILITIES : HIGH MASS FOR HIGH LUMINOSITY AND LARGE HABITABLE ZONE, LOW MASS FOR LONG LIFE ON MAIN SEQUENCE. SAYS THAT MOST LIKELY STARS TO SUPPORT LIFE ARE SUNLIKE.

GIVES 1 EVERY 10 L.Y. OR SO AS POSSIBLE DISTANCE BETWEEN LIFE-BEARING PLANETS. CHEMISTRY GIVES SPIRAL ARMS OF GALAXY (MORE EVOLVED GAS) SLIDE

SO IT IS CONCEIVABLE THAT LIFE IS OUT THERE ONLY ABOUT 10 L.Y. AWAY WHETHER OR NOT IT IS ON MARS, ETC. THIS PROBABILITY IS AT LEAST AS GOOD AS THE PROBABILITY THAT WE ARE ALONE, AND WOULD GIVE BILLIONS OF LIFE SITES IN OUR GALAXY.

IN THIS CONTEXT THAT THE EXCITEMENT HAS BEEN GENERATED.

CAN LOOK FOR LIFE IN SOLAR SYSTEM BY EXBENSIVE LANDING PROJECTS. COULD DETECT VERY WIDE VARIETY OF LIFE-FORMS IN PRINCIPLE, MICROBES TO SILICON-BASED WARTHOGS. BUT WE MIGHT JUST BE ALONE IN SOLAR SYSTEM WITH ALL THE OTHER GUYS OUT THERE AT INTERSTELLAR DISTANCES.

any way to investigate that ?

TRANSPARENCY : POSSIBLE INTERACTIONS

IF I LIMIT MY HAT-WEARING TO THAT OF AN ASTRONOMER FOR THE MOMENT (I'LL TRY OUT SOME REST OF THE WARBRODE IN QUESTION PERHAPS), IT'S IN INTERACTION WITHOUT CONTACT THAT THE ACTION STARTS.

TAKE ARECIBO. 1000-foot dish **SLIDE**  
S\*BAND RADAR )) 0.5 megawatts  
ANTENNA GAIN 71 dB  
RECEIVER SYSTEM TEMPERATURE 50°K  
ARECIBO-ARECIBO RANGE, DEPENDING ON CIRCUMSTANCES OF DETECTION ENVISAGED IS APPROACHING THE SIZE OF THE GALAXY.

ARECIBO COULD DETECT SIGNAL ONLY ABOUT 10<sup>4</sup> TIMES MORE POWERFUL THAN A TYPICAL TERRESTRIAL TV STATION AT INTERSTELLAR RANGE. AND THE SENSITIVITY OF RADIO TELESCOPES PICKED UP THIS MUCH IN THE LAST DECADE.

WE ARE ON THE THRESH-HOLD OF BEING ABLE TO DETECT OUR OWN LEVEL OF ELECTROMAGNETIC ACTIVITY AT INTERSTELLAR DISTANCES, IF WE KNEW HOW AND WHERE AND WHEN TO LOOK. SUGGESTS THAT SOON SENSITIVITY WOULD NOT BE LIMITING FACTOR PREVENTING DETECTION OF SIMILAR CIVILISATION TO OURSELVES, BUT OBSERVING DETAILS (POINTING, FREQUENCY ETC.)

SUN IS NOT AN OLD STAR. OTHER SUNLIKE STARS FORMED LONG BEFORE IT, AND WE KNOW OF NO OBSTACLE TO EVOLUTION OF LIFE AS WE KNOW IT NEAR THEM. UNLESS YOU ARE VERY PESSIMISTIC ABOUT THE LIFE EXPECTANCY OF TECHNICAL CIVILISATIONS ONCE THEY DEVELOP, IT IS LIKELY THAT ACCIDENTAL ELECTROMAGNETIC CONTACT BETWEEN EARLIER CIVILISATIONS HAS ALREADY TAKEN PLACE. THIS RAISES POSSIBILITY THAT WE TODAY MIGHT NOT HAVE THE DIFFICULT TASK OF DETECTING UNINTENTIONAL "LEAKAGE" TRANSMISSIONS FROM OUR GALACTIC NEIGHBOURS (WHICH MIGHT BE SHORT-LIVED DUE TO CABLE, LASERS, LIGHT-PIPES ETC.) BUT DELIBERATE, EASY-TO-DETECT, UNCRYPTIC "BEACON" SIGNALS. IT IS THE "BEACON CONCEPT" THAT HAS FIRED UP THE PRESENT SET OF EXPERIMENTS.

TRANSPARANCY: "STEPS TOWARDS CETI"

Suppose the steps have happened. ARE THERE ANY GENERAL CRITERIA FOR WHAT AN UNCRYPTIC BEACON TRANSMISSION MIGHT LOOK LIKE ? SUPPOSE WE WANTED TO MAXIMISE OUR DETECTABILITY WHEN DESIGNING A BEACON ? WHAT WOULD WE DO ?

# POSSIBLE INTERACTIONS WITH EXTRATERRESTRIAL LIFE

## 1. PHYSICAL CONTACT HERE.

- A. TODAY: UFO's, Little Green Men etc.  
Evidence anecdotal, hard to assess.  
Subject to hoaxing, fraud etc.
- B. IN PAST: "Chariots of the Gods", etc.  
Subject to misinterpretation if fail to consider ancient social order.

## 2. PHYSICAL CONTACT ELSEWHERE.

Space Exploration - limited to Solar System for the foreseeable future.

## 3. INTERACTION WITHOUT PHYSICAL CONTACT

Radio signals = ACCIDENTAL, e.g. TV spillover  
= DELIBERATE, e.g. "Beacons"

Laser signals - limited in range by interstellar dust

Artifacts - old spaceships, e.g. Pioneer 10

ESP, etc - speculative !!

# Steps Towards C.E.T.I.

## Required Somewhere else

FORMATION OF ECOSPHERE

ORIGIN OF LIFE

BIOLOGICAL EVOLUTION To energy manipulation

CONCEPTUAL EVOLUTION } To "technical

SOCIAL EVOLUTION } communicative" state

- includes apparatus and desire for contact.

## Required here

IDENTIFICATION of SOURCE of "signal"

METHOD of "signalling"

CONTENT of "signal"

Of all known radiations, interstellar space is most transparent to. RADIO WAVES

GRAVITY WAVES (hard to launch, detect)

NEUTRINOS (hardly interact at all with matter).

Only RADIO gives us "interstellar range" in 1974



MAXIMIZE THE RANGE FOR GIVEN POWER - use radio, to avoid attenuation  
SLIDE; DUST CLOUD

MINIMIZE THE COMPETING RADIO BACKGROUND:

- use 1 to 10 GHz through atmospheres like ours (H<sub>2</sub>O problem)
- use 1 to 100 GHz more generally. SLIDE: WINDOW

MAKE THE SIGNAL DISTINGUISHABLE FROM NATURAL SOURCES

- make it narrow-band, modulate it in some highly nonrandom way.
- BUT NARROW-BANDING MAKES IT HARDER TO FIND, SO NEED TO SET IT AT SOME 'SIGNIFICANT' FREQUENCY, OR AT MANY 'SIGNIFICANT' FREQUENCIES. MODULATION SHOULD BE FM, NOT AM, TO MAXIMIZE DETECTABILITY - NEVER TURN THE SIGNAL OFF.

THE EXPERIMENTS:

1. The hydrogen line.

MOST UBIQUITOUS ELEMENT IN UNIVERSE, ITS MOST DISTINCTIVE NATURAL LINE FREQUENCY IN THE MINIMUM-NOISE REGION. ALSO IN THE EARLIER DAYS THE ONLY RADIO SPECTRAL LINE KNOWN.

~~SLIDE~~ Life Search Projects.

Drake, OZMA 1960 TAU CETI  
EPSILON ERIDANI  
NRAO 85-foot Ten~~s~~ of hours

Troitskii, Gorky 45-foot, September and October 1968  
Twelve stars out to 62 L.Y.  
30 cm (available receiver)

Troitsky, small antennas in Gorky and Crimea, and Siberia  
Search for pulses at 50, 30, 16 cm pointing at zenith  
September-November 1970

1972 Verschuur, NRAO, Ozma again but ten stars, nearby, <sup>Sunlike</sup> astronomy

1973 Palmer and Zuckerman, Ozma again but 300 stars, 300-foot  
Most complete survey yet, looking for narrow, variable-velocity lines. Nothing confirmed. Single stars. SLIDE: 300

1974 Dixon (OSU) Whole-sky scanning for variable 21-cm

Transparency: 21-cm line versus water line

WATER IS STUFF OF LIFE. DISCOVERY OF OH at 1660 MHz - water hole near minimum noise

Merits of 22-GHz water line - confusion around galaxy less in angle (worse if you happen to hit a maser)  
astronomical anomaly of masers  
biological significance

Strategy - look for any signals from stellar systems  
Pilot project on 13 nearby single Sunlike, or planet-likely stars  
Next step, survey out to 30 L.Y.

But near may not be best. Transparency: detectability statistics

Suppose a very few very powerful transmitters, e.g. stellar luminosity. These might be more easily detected at great distances

21-cm line (1420 MHz) ATOMIC HYDROGEN

MOST ABUNDANT ELEMENT IN UNIVERSE  
FREQUENCY NEAR BACKGROUND NOISE  
MINIMUM

SENSITIVE RECEIVERS AVAILABLE NOW

STRONG CONFUSION WITH NATURAL SOURCES  
WITHIN MILKY WAY IN ALL DIRECTIONS  
— this is not a problem for extragalactic listening.

1.4-cm line (22,235 MHz) MOLECULAR WATER

BIOLOGICAL SIGNIFICANCE

ASTRONOMICAL MASER ANOMALY

NATURAL SIGNALS SHARPLY LOCALISED —

DO NOT CONFUSE LOCAL SEARCH.

Consider civilisations radiating power  $P$  watts

Minimum detectable signal =  $S_{min}$  watts/m<sup>2</sup>

Then maximum distance to which they can be detected is  $D_{max}$ , where

$$S_{min} = \frac{P}{4\pi D_{max}^2}$$

Let space density of such civilisations be  $f(P)$

Number  $N(P)$  detectable out to  $D_{max} = \frac{4}{3}\pi D_{max}^3 f(P)$

$$\text{Hence } N(P) = f(P) \frac{S_{min}^{-3/2} P^{3/2}}{6\pi}$$

$\log P$



$$\text{Suppose } f(P) = f_0 P^{-\alpha}$$

$$\text{Then } \frac{N(P > P^*)}{N(P < P^*)} = \frac{\int_{P^*}^{P_{max}} N(P) dP}{\int_0^{P^*} N(P) dP}$$

i.e.  $\frac{\text{No. of detectable civilisations brighter than power } P^*}{\text{No. of detectable civilisations fainter than power } P^*}$

$= \frac{\left(\frac{P_{max}}{P^*}\right)^{5/2-\alpha} - 1}{1}$

This is  $> 1$  if  $\left(\frac{P_{max}}{P^*}\right)^{5/2-\alpha} > 2$

EASILY SATISFIED IF  $\alpha < \frac{5}{2}$

than 'reasonable' signal levels nearby.

#### HYDROGEN-LINE EXTRAGALACTIC

Advantages: can monitor millions of stars at once  
direction problem solved  
radial velocity of galaxy Doppler-shifts away from your  
local confusion  
unique velocity of galactic nucleus for transmitter freq.

Arecibo 1000-channel correlator to do 50 nearest galaxies in its  
dec range. Expect bandwidth to distinguish. Put galactic band across  
the spectrometer and differentiate the spectrum to look for finer-scale  
structure than expected naturally.

AGAIN: any signal is a start. Ask about modulation later.

What if we get a signal ?

1. Communication slow for any case. Mainly knowing it's there.
2. Expect theoreticians to try to explain
3. Even if became convinced non-random, don't expect to decode
  - a) beacons not likely to convey large info. rates.  
could search in freq. once identified a sender and solved the  
pointing problem
  - b) language, etc. SLIDE: Dolphins, *Surveyor spacecraft & Moon/Mer*

Is it all a waste of time, because we can't prove it will succeed ?

Conferences these days to talk about probabilities, make estimates.

But the point is there are fundamental gaps, e.g. origin of genetic  
code, life expectancy of civilisations.

Probability that electromagnetic spectrum is teeming with beacons is  
no less than that we are alone.

Questions raised are fundamental :

Are processes which led to us unique to Earth ?

What is abundance of life in Universe and what is ultimate relation  
of living to non-living matter ?

Questions of philosophy and destiny creep in and are hard to put aside  
once raised. Is life the mindless reproduction of the nucleic acids  
with Man as a particularly baroque factory ?

A step, however implausible, towards answering uniqueness questions  
is technically possible and not forbidden by any known facts.

So various strategies possible :

Search strategies.

Ultimate pessimistic - do nothing. That way you are sure of the results and cannot be accused of wasting time or money. Unfortunately absence of evidence also tells you nothing. Nevertheless this is a very common approach.

Ultimate optimistic - drop the space program and astronomy and spend all the time (astronomy) and money (space program) on experiments specifically designed to search for life. But it would take thousands of years to search all frequencies and all probable stars and then might not succeed because looked at wrong time or were unable to understand patterns, etc. Also present space and astronomy research has helped formulate present problem, so future research also likely to be helpful. Besides which, Earth may need space engineering for survival and there are other interesting astronomical problems to do with origin of Man and our self-view (origin of Solar System, cosmology, etc.)

Just do ordinary astronomy - could trip up over civilisations, e.g. by finding things like pulsars. This could well work but radio astronomers are in fact most interested in star formation, star death and peculiar 'radio stars' that are unlikely to incubate life. Limited to Sky Survey data where data gathering is short and data analysis crude. Altho pulsars so found, these are broad-band objects. Beacons might be broad band, but it is reasonable to suppose beacon design may assume some interest in beacon being found, hence concentration to 'biofrequencies' and lines of astronomical interest.

AHB recipe - improve on just doing ordinary astronomy but utilize the ordinary astronomy equipment if it is capable of doing something that greatly increases probability of success. e.g. Ozma, water-line experiments. Then can improve chances cheaply without taking much time. Also there is problem of rapid technical advance - good telescopes become obsolete quickly. Good way of keeping ten-year-old telescopes in use. If find something, can quickly check it out on modern equipment.

Monitor small # of nearby \*'s in detail.

~~Don't skimp the estimates, what~~ large # of other \*'s briefly (noise & low likely to be compensated by v. strong beacon)

external galaxies in 21cm line.

H<sub>2</sub>O or SOL.Y. → 3 Megawatt transmitter (isotropic)

Water-vapour line

Lowest pure rotational transition in ground vibrational state of water molecule lies at ~~22.235080~~ <sup>22.235080</sup> GHz (1.348 cm).

When anomalous OH radical emission detected in interstellar gas clouds, search for water molecules carried out, expecting only weak signals.

But found intense, variable signals from exceedingly small sources (0.5 milliarc sec) in many OH-emitting regions. Apparent brightness temperatures  $>10^{13}$  K show probably maser action. Time-scale for 100% variability of order a few weeks, source sizes less than about 10 A.U. Possibly ~~water~~ water clouds in prestellar nebulae, masers being pumped by infrared radiation from protostar.

Detailed mechanism very uncertain.

Note: confusion around galactic plane much less than for 21 cm in angular terms, but much worse in brightness *if* you happen to hit it.

Brightest line 'temperatures' of any yet found, an attractive astronomical puzzle.

Biological significance  
Astronomical anomaly  
In minimum-noise window

Don't expect "refined" signals from 4's,  
∴ can look for any emission first,  
then rest for "beacon character".

A bit high for max. information but satisfies unambiguous quality of beacon signal. If found "beacon", search same neighborhood of all freqs (spatial dimension of search removed) to find actual "control information channels". Might be different levels of control on different freqs.