

THE SEARCH FOR INTERSTELLAR CIVILISATIONS

AT PRESENT 6 GROUPS OF ASTRONOMERS IN U.S., RUSSIA AND CANADA ARE LISTENING FOR RADIO SIGNALS WHICH MIGHT HAVE BEEN TRANSMITTED BY DISTANT CIVILISATIONS AMONG THE STARS.

THESE ARE SPECULATIVE EXPERIMENTS WHICH NOBODY EXPECTS TO GIVE INSTANT SUCCESS. NOT EVEN THOSE OF US WHO ARE DOING THEM.

BUT FACT THAT SUCH SEARCHES ARE BEING CARRIED OUT WITH SOME OF THE MOST SENSITIVE RADIO DETECTION EQUIPMENT ON EARTH <sup>INDICATES</sup> ~~SUGGESTS~~ THAT THE SEARCH FOR ADVANCED LIFE BEYOND THE EARTH IS FINALLY LEAVING THE REALM OF SCIENCE FICTION AND BECOMING A REASONABLY RESPECTABLE BRANCH OF SCIENCE ITSELF.

WILL TRY TO EXPLAIN WHY THIS RESPECTABILITY POSSIBLE IN MID-1970'S AND WHY I DECIDED TO GET INVOLVED WITH THIS KIND OF EXPERIMENT

ARE NOW ATTEMPTING THIS LISTENING

OUR ENVIRONMENT IS

1. ~~WE ARE~~ NOT OBVIOUSLY SPECIAL

<sup>16th Century</sup>  
FIRST IMPORTANT STEP WAS POLISH CLERIC NICOLAS KOPERNICK (COPERNICUS) CONVINCING HIS CONTEMPORARIES THAT EARTH WAS NOT CENTRE OF UNIVERSE. (Slide)

openings

SO MAN DOES NOT INHABIT THE MOST SIGNIFICANT OBJECT IN THE UNIVERSE.

20-TH CENTURY ASTRONOMY TAKES THIS MUCH FURTHER.

Way Star Field  
1st of Galaxy

UNIVERSE IS IMMENSE. SUN IS ONLY ONE OF SEVERAL HUNDRED BILLION STARS IN OUR GALAXY (Slides). <sup>SUN IS</sup> ATOMIC SCALE ON THIS SLIDE. EARTH ORBIT SIZE OF ELECTRON ORBIT IN ATOM. GALAXY:STAR RATIO SAME AS STAR:MAN, SAME AS MAN:ATOM.

60-inch tel  
131  
coma  
Auricles  
1st star cl.

GALAXY IS ONLY ONE OF BILLIONS IN UNIVERSE. (Slides)

NOTHING OBVIOUSLY SPECIAL ABOUT OUR LOCATION IN SPACE.

periscope  
stellar spec.  
Abundances.  
life Chemistry

ASTRONOMICAL SPECTROSCOPY TELLS US CHEMICAL ABUNDANCES <sup>(Slides)</sup> 'OUT THERE'. SAME KINDS OF ATOMS EVERYWHERE. CARBON, HYDROGEN, OXYGEN, NITROGEN, PHOSPHORUS, IRON, MAGNESIUM, AMONG MOST ABUNDANT CHEMICAL ELEMENTS ALL OVER DISK OF OUR GALAXY. (Slide)  
NOTHING PARTICULARLY SPECIAL ABOUT THE CHEMICAL MAKEUP OF OUR SOLAR SYSTEM AS A WHOLE.

End Slides  
for  
while.

IF LIFE EXISTS IN THIS APPARENTLY VERY ORDINARY PLACE DOES THIS MEAN LIFE IS WIDESPREAD THROUGHOUT THIS IMMENSE UNIVERSE ?

## 2. WHY BOTHER ?

AS BIOLOGISTS I AM SURE YOU WOULD BE INTERESTED IN CONTACT WITH OTHER LIFE FORMS TO SEE HOW THEY WORKED - WHAT OTHER OPTIONS ARE POSSIBLE.

BUT CONTACT WITH OTHER LIFE WOULD DO FAR MORE THAN JUST INCREASE THE SCOPE OF UNDERGRADUATE BIOLOGY CLASSES, OR PROVIDE A CROP OF NEW BIOLOGY PH.D. THESIS TOPICS.

*Despite 400 years since Copernicus*

MAN IS USED TO THINKING OF HIS SOCIAL PROGRESS, OF HIS GOALS, AS THE ONLY ONES, OF HIS HISTORY AS THE ONLY HISTORY, AND OF HIS DESTINY AS THE ONLY DESTINY. CONTACT WITH OTHER LIFE WOULD INTRODUCE A NEW CALCULUS OF ALL THESE AREAS.

AND BY CONTACT WE NEED NOT MEAN PHYSICAL CONTACT, OR <sup>TWO-WAY</sup> ~~ONE-WAY~~ COMMUNICATION. WE HAVE NEITHER PHYSICAL CONTACT NOR TWO-WAY COMMUNICATION WITH THE ANCIENT GREEKS. YET WE CAN BE INFLUENCED BY THEM AND LEARN FROM THEM, BECAUSE WE HAVE A ONE-WAY SIGNAL FROM THEM CONTAINING CODED INFORMATION THAT WE CAN TRANSLATE INTO MODERN LANGUAGE.

LOCATION OF ONE CONVINCING EXTRATERRESTRIAL SIGNAL ~~IN A~~ FORM WE COULD ATTRIBUTE TO ~~AN INTELLIGENT SENDER WOULD~~ <sup>SELF-VIEW</sup> ~~BE A TURNING-POINT IN HUMAN HISTORY AS IMPORTANT AS~~ <sup>THAT PRODUCED BY</sup> ~~THE~~ OF COPERNICUS. ~~\_\_\_\_\_~~

<sup>OF CONTACT</sup> WHAT ARE THE CHANCES, AND WHY TRY TO EXPLOIT THEM NOW ? ~~\_\_\_\_\_~~

## 3. WHAT IS LIFE ?

AS AN ASTRONOMER I'M WALKING ON SOMEONE ELSE'S THIN ICE HERE, BUT I SHOULD EXPLAIN WHAT I UNDERSTAND BY IT IN CASE WE HAVE DIFFERENT CONCEPTS.

BUDDHIST MONK CALLED BANKEI ONCE CHALLENGED TO DEMONSTRATE A MIRACLE BY FOLLOWER OF ANOTHER MONK WHO HAD ALLEGEDLY PERFORMED MANY MIRACLES. BANKEI REPLIED 'MIRACLE IS THAT WHEN I FEEL HUNGRY I EAT AND WHEN I FEEL THIRSTY I DRINK'.

TO ME, BANKEI HAD DEFINED THE <sup>TRUE</sup> ONE MIRACLE OF LIFE.

NAMELY THAT LIFE TEMPORARILY HALTS THE BEST-ESTABLISHED TREND IN THE ENTIRE UNIVERSE - THE TREND TOWARDS EVER-INCREASING MOLECULAR CHAOS. ALL MATTER TENDS TO BECOME MORE AND MORE DISORDERED AS TIME PASSES. OLD BUILDINGS FALL INTO HEAPS OF RUBBLE. RUBBLE HEAPS NEVER SPONTANEOUSLY ASSEMBLE THEMSELVES INTO BUILDINGS. SHINY CARS RUST IN WRECKERS' YARDS. RUSTED HULKS NEVER SPONTANEOUSLY BECOME NEW CADILLACS. NOT EVEN NEW TOYOTAS.

<sup>TREND TOWARDS DISORDER</sup> THERMODYNAMICS SUMMARISES THIS BY SAYING THAT THE ENTROPY OF THE UNIVERSE STEADILY INCREASES - THINGS WILL GET WORSE BEFORE THEY GET STILL WORSE.

LIVING MATTER FLEETINGLY MAINTAINS ITSELF AS AN OASIS OF LOW ENTROPY IN A DIRORDERING

UNIVERSE BY TAKING IN LOW-ENTROPY MATTER (FOOD) OR LOW-ENTROPY RADIATION (SUNLIGHT) AND EXCRETING HIGHER\*ENTROPY MATTER (WASTES) OR HIGHER-ENTROPY ENERGY (HEAT). LIFE THUS KEEPS ITS OWN ENTROPY LOW AT THE EXPENSE OF INCREASING THE RATE OF DISORDERING OF EVERYTHING AROUND IT.

I THINK OF LIFE AS SOMETHING THAT

~~IT~~ BORROWS LOW-ENTROPY ENERGY TO FINANCE ITS OWN INTERNAL PROCESSES, MAINTAINING OR GROWING OR DUPLICATING ITS OWN PECULIAR ORGANISATION, THEN REPAYES THAT ENERGY TO THE ENVIRONMENT IN A HIGHLY DEPRECIATED CURRENCY WHOSE ENTROPY IS MUCH HIGHER.

So LIFE NEEDS MORE THAN JUST AN ENVIRONMENT THAT PERMITS ITS STRUCTURE TO EXIST, IT NEEDS ONE CAPABLE OF FEEDING IT LOW-ENTROPY ENERGY AND ACCEPTING HIGH-ENTROPY ENERGY IN RETURN.

4. WHERE IN THE UNIVERSE COULD LIFE EXIST ?

MOST PEOPLE THINK THE ANSWER IS 'ON PLANETS'. THIS MAY BE EXCESSIVELY CHAUVINISTIC, A RESULT OF FINDING OURSELVES TO HAVE EVOLVED ON ~~THE~~ <sup>A PLANET.</sup> BUT ~~IT~~ <sup>SUGGESTS THAT PLANETARY CHAUVINISM</sup> A QUICK LOOK AT THE OTHER POSSIBILITIES THE UNIVERSE PROVIDES ~~IT~~ <sup>MAY ACTUALLY BE CORRECT.</sup>

(Side)

cluster

MOST OF THE UNIVERSE IS EMPTY, OR NEARLY EMPTY. THE SPACE BETWEEN THE STARS IS <sup>Full of</sup> ~~EMPTY~~ LOVELY LOW-ENTROPY STARLIGHT BUT THE MATTER THERE IS AT SUCH TINY DENSITIES (EVEN 10 ATOMS PER CC. OR A DENSITY ABOUT  $10^{-23}$  OF THAT OF WATER IS REFERRED TO BY ASTRONOMERS AS AN 'INTERSTELLAR CLOUD') THAT ENCOUNTERS BETWEEN ATOMS OCCUR ONLY ABOUT ONCE EVERY 10,000 YEARS PER ATOM. THIS WOULD MAKE BIOPROCESSES DIFFICULT, IF NOT IMPOSSIBLE (FRED HOYLE'S STORY 'THE BLACK CLOUD' IS FOOD FOR THOUGHT HERE).

fav inferior

AT THE OTHER EXTREME? MOST OF THE MATTER IN THE KNOWN UNIVERSE IS IN STARS, WHERE THE ORGANISATION OF MATTER IS SO DOMINATED BY GRAVITY THAT ONLY NUCLEAR PROCESSES STOP IT BEING SQUEEZED INTO A PULP OF PURE NEUTRONS IN A MATTER OF MINUTES. THE BATTLE BETWEEN NUCLEAR PHYSICS AND GRAVITY THAT WE CALL A STAR <sup>(Side)</sup> PRODUCES HUGE ENERGY FLOWS AND TEMPERATURE GRADIENTS THAT ARE NOT AT ALL CONDUCTIVE TO THE KIND OF PROCESSES WE CALL LIFE.

PLANETS PROVIDE AN INTERMEDIATE ENVIRONMENT BETWEEN THESE EXTREMES ~~IT~~. CLOSE ENOUGH TO STARS TO BENEFIT FROM LOW-ENTROPY STELLAR ENERGY, YET ABLE TO RADIATE HEAT AWAY INTO ~~COLD INTERSTELLAR~~ SPACE IN MOST DIRECTIONS. MATTER ON PLANETS IS DENSE ENOUGH FOR THERE TO BE FREQUENT INTERACTIONS BETWEEN ATOMS YET NOT SO DENSE THAT THESE INTERACTIONS, MAINLY ELECTRICAL IN NATURE, GET OVERWHELMED BY GRAVITY. THE ABUNDANCE OF LIFE IS THEREFORE QUITE LIKELY TO BE CONNECTED WITH THE ABUNDANCE OF PLANETS, NEAR STARS. MINI-STARS, OR STAR-LESS PLANETS, EVEN IF THEY EXIST, ARE UNLIKELY TO SUPPORT LIFE AS WE KNOW IT.

5. HOW MANY STARS HAVE PLANETS ?

WE CANNOT DIRECTLY SEE PLANETS TRAVELLING AROUND OTHER STARS. PLANETS SHINE BY REFLECTING THE LIGHT OF THEIR STAR, AND SO PRODUCE FAINT IMAGES TOO CLOSE TO THEIR STARS' IMAGES FOR US TO BE ABLE TO SEE THEM FROM EARTH. SUCH EVIDENCE AS THERE IS FOR PLANETS AROUND OTHER STARS COMES FROM SEEING THE STARS THEMSELVES WOBBLE ACROSS THE SKY AS IF UNDER THE GRAVITATIONAL PULL OF SMALL UNSEEN COMPANIONS. THESE OBSERVATIONS ARE BOTH TRICKY AND CONTROVERSIAL AT THE PRESENT TIME.

THE MAIN REASON FOR EXPECTING PLANETS TO BE COMMON IS BASED ON OUR PICTURE OF HOW STARS COME TO BE BORN (Slide). POCKETS OF INTERSTELLAR GAS COLLAPSE UNDER GRAVITY TO MAKE STARS. GAS IS STIRRED UP BY STELLAR RADIATION AND EXPLODING STARS SO HAS SOME ROTATION BEFORE IT COLLAPSES TO MAKE A STAR. THEN VERY BASIC PHYSICS SHOWS THAT THIS INITIAL ROTATION MUST BE AMPLIFIED AS THE GAS CONTRACTS, MAKING IT FRAGMENT INTO EITHER SEVERAL STARS MOVING AROUND ONE ANOTHER (A MULTIPLE STAR SYSTEM), OR PLANETS MOVING AROUND A CENTRAL STAR.

Region

Observations show the gas has

note

(Slide)

ABOUT HALF OF ALL KNOWN STAR SYSTEMS ARE MULTIPLES. THE OTHER HALF - SINGLE STARS - WE EXPECT TO GENERALLY HAVE PLANETS, GIVING US AN EXPECTATION OF OVER 100 BILLION PLANETS IN OUR GALAXY ALONE.

6. HOW MANY PLANETS COULD SUPPORT LIFE ?

OUR ANSWER TO THIS IS SKETCHY, AS WE HAVE ONLY SEEN ONE LIFE MECHANISM IN ACTION. ALL EARTH LIFE, DESPITE ITS TREMENDOUS SUPERFICIAL VARIETY OF FORMS, IS BASED ON THE SAME CARBON-COMPOUND-IN-WATER CHEMISTRY. SO WE DON'T KNOW IF OTHER BIOCHEMISTRIES WOULD ACTUALLY BE VIABLE.

CAN'T DO STATISTICS WITH ONLY ONE SAMPLE - GET BIASED ESTIMATE OF MEAN AND NO ESTIMATE WHATSOEVER OF VARIANCE - DON'T KNOW WHETHER CARBON-COMPOUND-IN-WATER MECHANISM <sup>FOR LIFE</sup> IS ONLY ONE POSSIBLE, OR WHETHER IT'S ONE OF MANY POSSIBILITIES.

BUT I PRESUME THAT THE PROBABILITY THAT ANY ENVIRONMENT SUPPORTS LIFE, P(LIFE) = P(LAWKI) + P(UNKNOWN). SO LOOKING AT P(LAWKI) GIVES US A MINIMUM ESTIMATE.

TWO OF TEN PLANETS IN OUR SOLAR SYSTEM COULD PROBABLY SUPPORT LAWKI - MARS AND EARTH. MARS JARS EXPERIMENTS (Slide) SUGGEST THAT VERY SIMPLE EARTH ORGANISMS CAN SURVIVE MARTIAN CONDITIONS. POSSIBLY VIKING IN JULY WILL HAVE MORE TO SAY ON THIS.

Mars Jar

FOR LAWKI EARTH IS IN 'HABITABLE ZONE' AROUND SUN, MARS MAYBE JUST ON OUTER EDGE. FOR ANY STAR CAN DEFINE INNER LIMIT OF HABITABLE ZONE FOR LAWKI (LAWKI FRIES) AND OUTER LIMIT (LAWKI FREEZES) - Slide.

THE HABITABLE ZONE SIZE FOR LAWKI INCREASES WITH STAR LUMINOSITY. PROBABILITY OF FINDING PLANET IN LAWKI-HABITABLE ZONE IS GREATER THE MORE LUMINOUS THE STAR.

Habitable zone

MOST LIKELY PLACES TO FIND PLANETS HABITABLE BY LAWKI

SO OTHER THINGS BEING EQUAL THE GREATEST PROBABILITY OF FINDING HABITABLE PLANETS ARE AROUND MORE LUMINOUS STARS.

cellular evolution

BUT OTHER THINGS ARE NOT EQUAL. ~~PLANETS~~ ALSO NEED GESTATION TIME FOR LIFE ON PLANET. MOST LUMINOUS STARS BURN UP ~~THEIR~~ THEIR LONG-TERM ENERGY SUPPLY FASTEST AND HAVE SHORT LIFETIMES. SO IN FACT INTERMEDIATE-LUMINOSITY STARS MOST LIKELY (Slide) TO SUPPORT LIFE.

THIS NARROWS US DOWN TO ABOUT ONE STAR IN THREE OF ALL SINGLE STARS, I.E. ABOUT ONE IN SIX ALTOGETHER.

THIS STILL GIVES US OVER 10 BILLION ~~100 MILLION~~ STARS IN OUR GALAXY ALONE. LIKELY TO HAVE PLANETS THAT COULD SUPPORT LAWKI.

PLANETS WITH RIGHT

7. GIVEN CHEMISTRY, DO WE GET LIFE ?

~~THE CHEMISTRY FOR LIFE AS WE KNOW IT IS ALL OVER OUR GALAXY, ESPECIALLY IN THE SPIRAL ARMS.~~ LAWKI BASED ON SOME OF MOST ABUNDANT CHEMICAL ELEMENTS IN UNIVERSE AFTER HYDROGEN AND HELIUM (EARLIER SLIDE), AND WE CAN ~~WE CAN~~ EXPECT SEVERAL BILLION POSSIBLE 'LIFE SITES' WITH APPROPRIATE CHEMISTRY IN OUR GALAXY. DOES THIS MEAN WE SHOULD EXPECT A GALAXY TEEMING WITH LIFE ?

ORIGIN OF LIFE

INVADES

IF ORIGIN OF LIFE RELIES ON NOT-TOO-IMPROBABLE PROCESSES, ANSWER IS YES. IF ~~IT~~ SOME INCREDIBLE FREAK, THEN MAYBE NOT. PROBLEM IS THAT WE CANNOT BE AT ALL SURE EXACTLY HOW PROBABLE ORIGIN OF LIFE IS, GIVEN A PLANET WITH THE RIGHT CHEMISTRY.

WE NEVER SEE LIFE ORIGINATE NOW WITHOUT BEING PRECEDED BY OTHER LIFE WHICH HAS CRUCIAL ROLE IN PROVIDING THE ORGANISATION FOR THE NEW LIFE.

CHEMICAL EXPERIMENTS HAVE SHOWN THAT GIVEN PLAUSIBLE PRIMEVAL EARTH ENVIRONMENT CONTAINING SIMPLE ABIOLOGICAL MATERIALS, THEN A WIDE VARIETY OF CHEMICAL INGREDIENTS OF EARTH LIFE CAN BE BUILT UP BY RANDOM OR NEARLY-RANDOM PROCESSES INVOLVING ENERGY SUPPLIES THAT ARE NOT EXOTIC BUT READILY AVAILABLE, e.g. ULTRAVIOLET RADIATION FROM SUN, COSMIC RAYS, HEAT, ETC. ~~THIS~~

|||||

COMPLETELY ABIOLOGICAL SYNTHESIS OF SUCH IMPORTANT MATERIALS AS AMINOACIDS, ATP, SOME PROTEIN-LIKE CHAIN MOLECULES, ETC. FROM A TOTALLY INANIMATE ENVIRONMENT HAVE BEEN DEMONSTRATED ON LABORATORY TIME-SCALES. ALL THAT SEEMS TO BE NEEDED IS AN ENERGY SUPPLY ADEQUATE TO BREAK BONDS OF SIMPLE MOLECULES LIKELY TO EXIST ON PRIEMVAL PLANET, AND A SHELTER FOR COMPLICATED PRODUCTS FROM BEING REBROKEN INTO SIMPLE MOLECULES AGAIN. PUDDLES, LAKES ~~ARE IDEAL~~. IDEAL BECAUSE EVAPORATION CAN HELP CONCENTRATE PRODUCTS.

VERY BASIC

LIFE FORM

~~THESE~~ THESE SIMPLE EXPERIMENTS INDICATE THAT THE INGREDIENTS OF OUR ~~THESE~~ MAY EVOLVE RANDOMLY. BUT HAVING INGREDIENTS IS NOT HAVING CAKE. WHAT IS THE ORIGIN OF THE CODING THAT CAN ORGANISE THE CHEMICAL OF LIVING MATTEE INGREDIENTS INTO A VIABLE LIVING SYSTEM ?

WE DO NOT KNOW HOW THE CODING OF EARTH LIFE ORIGINATED

WE MAY NEVER KNOW, BECAUSE A LAB DEMONSTRATION THAT THE GENETIC CODING MATERIALS COULD APPEAR RANDOMLY FROM SOME ABIOLICAL GUCK WOULD NOT PROVE THAT THIS WAS THE WAY THEY DID APPEAR LONG AGO.

WHETHER OR NOT LAB EXPERIMENTS CAN PRODUCE GENETICALLY SIGNIFICANT MOLECULES FROM INANIMATE MATTER, WE MAY HAVE ORIGINATED THROUGH NON-RANDOM PROCESSES WHOSE PROBABILITY WE CANNOT ESTIMATE BY TERRESTRIAL EXPERIMENTS, OR EVEN BY ANY EXPERIMENT.

e.g. THE ORIGIN MAY INVOLVE PROCESSES BEYOND THE SCOPE OF SCIENCE - "GOD"

<sup>THE ORIGIN MAY INVOLVE</sup>  
OR PROCESSES BEYOND THE SCOPE OF INVESTIGATION CONFINED TO EARTH, e.g. IF THE FIRST GENETIC MATERIAL ON EARTH CAME FROM OUTSIDE EARTH, IN A DELIBERATELY DIRECTED 'BIOCAPSULE' LAUNCHED FROM ~~ELSEWHERE~~ OR ACCIDENTLY IN THE SANDWICH LUNCH OF A VISITING ASTRONAUT (Slide).

(SOBERING TO THINK THAT WE DON'T KNOW THAT WE DIDN'T EVOLVE FROM A PRIMEVAL SALAMI SANDWICH LEFT BEHIND ON EARTH BY SOME ANCIENT ASTRONAUT.)

<sup>WE</sup> WE DO NOT HAVE, AND MAY NEVER HAVE, ENOUGH <sup>DATA FROM PURELY</sup> ~~CONFIDENCE BASED ON~~ EARTH-BASED EXPERIMENT TO TELL US WHETHER TO EXPECT OUR GALAXY TO BE TEEMING WITH LIFE, OR ~~TO~~ TO EXPECT THAT WE ARE AN ISOLATED, BAROQUE EXAMPLE OF CARBON CHEMISTRY GONE PECULIAR, NEVER TO BE REPEATED ELSEWHERE.

IT IS THIS POSSIBLY FUNDAMENTAL LACK OF KNOWLEDGE <sup>THAT</sup> MAKES ME WANT TO LOOK IN WHATEVER WAYS ARE POSSIBLE FOR LIFE ELSEWHERE.

NASA CAN <sup>LOOK</sup> ~~DO~~ WITH EXPENSIVE, SHORT-RANGE, LANDING MISSIONS <sup>CONFINED TO</sup> ~~IN~~ <sup>INNER</sup> SOLAR SYSTEM FOR <sup>IMMEDIATE</sup> FUTURE. BUT OUR TECHNOLOGY GIVES US ONE, ~~TO~~ CHEAP AND LONG-RANGE ~~ALTERNATIVE APPROACHES.~~ <sup>ALTERNATIVE APPROACH.</sup>

<sup>PROBABLY</sup> 8. WE ARE <sup>PROBABLY</sup> LATECOMERS, IF "OTHERS" EXIST.

RADIOACTIVE DATING OF EARTH ROCKS, MOON ROCKS AND METEORITES SUGGEST THAT THE SOLAR SYSTEM FORMED 4.5 TO 5 BILLION YEARS AGO. ASTRONOMICAL DATING OF STAR GROUPS IN OUR GALAXY SUGGESTS THAT SOME FORMED AS LONG AS 12 BILLION YEARS AGO, JUDGING BY THE STARS THEY CONTAIN.

WHAT THIS MEANS IS THAT IF 'OTHERS' - OTHER LIFE-FORMS - EXIST OUT THERE WE ~~ARE~~ ARE NOT LIKELY TO BE AMONG THE FIRST. INDEED ASTRONOMICAL EVIDENCE SUGGESTS THAT RATE OF STAR FORMATION IN OUR GALAXY DECLINES AS MORE AND MORE INTERSTELLAR GAS GETS INCORPORATED INTO EXISTING STARS.

THIS MEANS THAT THE GREATEST RATE OF EMERGENCE OF LAWKI MAY HAVE BEEN IN THE PAST. WE ~~SHOULD~~ CONTEMPLATE THE POSSIBILITY THAT MORE EVOLVED LIFE IS OUT THERE, AND HAS BEEN OUT THERE FOR SOME TIME.

9. LONG DISTANCE - ALMOST LIKE BEING THERE, ONLY BETTER?

ELECTROMAGNETIC WAVES TRAVEL AT THE SPEED OF LIGHT AND USE ALMOST NO ENERGY COMPARED WITH MATTER TRANSPORT, WHICH IS BASICALLY SLOW AND ENERGETICALLY COSTLY. THE INFORMATION CONTENT OF A SIGNAL SENT BY ELECTROMAGNETIC WAVES CAN BE ENORMOUS FOR THE ENERGY INVESTMENT, COMPARED WITH MATTER TRANSPORT.

INTERSTELLAR SPACE IS NOT ~~TRANSPARENT~~ TRANSPARENT TO <sup>ALL</sup> ELECTROMAGNETIC WAVES, BECAUSE OF THIN DUST IT CONTAINS (Slides). BUT RADIO WAVES TRAVEL EFFECTIVELY FOREVER THROUGH THIS MATERIAL.

WE HAVE UNINTENTIONALLY SURROUNDED OUR PLANET WITH AN EXPANDING WAVE OF INFORMATION <sup>ABOUT OURSELVES</sup> - ALL OUR RADIO, TV AND OTHER BROADCASTS THAT HAVE LEAKED INTO SPACE SINCE WE BEGAN TO USE THESE MEDIA. THIS WAVE COULD BE DETECTED BY <sup>RADIO</sup> RECEIVERS <sup>NO MORE ADVANCED</sup> ~~SIMPLY FOR THE~~ THAN OUR BEST RECEIVERS BY ANY LISTENERS AROUND THE NEARBY STARS.

RADIO SIGNALS ARE A PARTICULARLY LIKELY WAY FOR ADVANCED CIVILISATIONS <sup>IF THEY EXIST</sup> TO BLUNDER INTO CONTACT WITH ONE ANOTHER, EVEN ACROSS INTERSTELLAR DISTANCES. OUR OWN TECHNIQUES WOULD ALLOW US TO DO THIS NOW, IF WE KNEW HOW AND WHERE TO LOOK. FOR THE "OTHERS"

SO IT'S NOT EXTRAPOLATING VERY FAR TO ENVISAGE THAT IF THERE ARE 'OTHERS' OUT THERE, AND RADIO CONTACTS HAVE BEEN MADE IN THE PAST, THAT FUTURE CONTACTS MIGHT ACTUALLY BE ENCOURAGED BY SETTING UP POWERFUL RADIO 'BEACONS' TRANSMITTING ~~SIGNALS~~ AT PARTICULARLY SIGNIFICANT OR UNUSUAL FREQUENCIES. IF WE WERE ~~ABLE TO DO THIS~~ <sup>TODAY,</sup> WE COULD EASILY HARNESS HUNDREDS OF MEGAWATTS OF POWER FOR SUCH A SIGNAL. AND OUR BEST EQUIPMENT COULD DETECT SUCH A SIGNAL MOST OF THE WAY ACROSS OUR GALAXY.

THIS HAS BEEN THE STIMULUS THAT LAUNCHED THE PRESENT ROUND OF EXPERIMENTS - THE REALISATION THAT WE COULD DETECT CIVILISATIONS NO MORE TECHNOLOGICALLY ADVANCED THAN OURSELVES, ACROSS INTERSTELLAR DISTANCES IF WE MERELY KNEW WHERE TO LOOK. SO THE PRESENT EXPERIMENTS USE THE BEST RADIO TELESCOPES TO SEARCH THE NEIGHBOURHOODS OF STARS FOR UNUSUAL SIGNALS AT A VARIETY OF FREQUENCIES (Slides). WE ~~ARE~~ EXPECT TO SEARCH MANY TARGETS AT MANY FREQUENCIES, TRYING VARIOUS IDEAS AT GUESSING PLACES TO LISTEN AND FREQUENCIES TO TUNE TO. WE OBVIOUSLY CANNOT EXPECT QUICK SUCCESS, SO FAR WE HAVE FAILED.

INDEED

THE GAPING HOLES IN OUR KNOWLEDGE ABOUT HOW LAWKI DEVELOPED HERE ON EARTH MAY CONTAIN HIDDEN FACTORS WHICH GUARANTEE THAT ALL SUCH EXPERIMENTS WILL FAIL.

MAYBE WE ARE A RARE COSMIC FREAK - A NUCLEIC-ACID ABERRATION NEVER TO BE REPEATED ELSEWHERE.

MAYBE TRULY ADVANCED CIVILISATIONS DO NOT SPEND VERY LONG DABBLING IN TECHNOLOGY. PERHAPS THEY FIND BETTER WAYS OF ADAPTING TO THEIR ENVIRONMENT. OR MAYBE THEY BLOW THEMSELVES TO SMITHEREENS.

MAYBE LAWKI ELSEWHERE COMMUNICATES THROUGH CHANNELS WE CANNOT EVEN IMAGINE, LET ALONE TUNE IN TO.

SO THE CHANCES OF SUCCESS IN THESE LISTENING EXPERIMENTS ARE SMALL. BUT WE DO NOT KNOW THAT THEY ARE ZERO, UNLESS WE ARE TOO PESSIMISTIC TO TRY.

**WE FIND**  
IF ~~OUR TELESCOPES REVEAL~~ NOTHING BUT SILENCE AMONG THE STARS, IT WILL BE FRUSTRATING. BUT THE POSSIBILITY OF ~~OUR~~ <sup>THAT</sup> FRUSTRATION IS MORE ACCEPTABLE TO ~~THOSE OF US DOING THE EXPERIMENTS~~ <sup>ME</sup> THAN THE FAR WORSE POSSIBILITY, <sup>WHICH IS</sup> THAT WE COULD BE <sup>NEEDLESSLY</sup> PROLONGING MAN'S ERA OF SELF-CENTRED ISOLATION SIMPLY BY NOT TRYING. **TO SEARCH FOR OUR COUSINS AMONG THE STARS.**