WHAT KIND OF ATMOSPHERES AROUND EXOPLANETS COULD BE SUGGESTIVE OF POSSIBLE EXISTENSE OF LIFE ON THEM? WOULD BE EXCITING TO SEE WATER VAPOUR OZONE (also IMPLIES PRESENCE OF O_2 AND SHIELDING FROM UV) AND POSSIBLY METHANE (OFTEN PROFUSELY PRODUCED FROM BIOACTIVITY SPECTRA OF EARTHSHINE CLEARLY SHOWS PRESENCE OF ALL 3 ABOVE CONSTITUENTS.

JWST EXPECTED TO LOOK FOR THESE SIGNATURES.

LIFE's PRIMARY SPECTRAL SIGNATURE LIKELY MIX OF OZONE, METHANE AND WATER VAPOUR

SPECTRUM OF EARTHSHINE, MOL. OXYGEN (near 690 and 760 nm) WATER VAPOUR (710 - 730 nm BAND and OZONE (650 - 850 nm BAND).

GJ 1132 b (1.4 Earth MASS), orbiting RED DWARF, SHOWS ATMOSPHERE RICH IN WATER AND METHANE

A WATER WORLD. TOO MUCH WATER, not DESIRABLE. DILUTION OF NUTRIENTS, DISSOLVED MATTER

VENUS LIKE PLANET (KEPLER 1649b, RUNAWAY GREENHOUSE.

POINT IS THERE MUST BE ENOUGH NUTRIENTS

UNIQUE PROPERTIES OF WATER MAKES LIFE POSSIBLE ON EARTH !

1. WATER H_2O is a LIQUID at ORDINARY TEMPS ALTHOUGH RELATED COMPOUNDS WITH MUCH HIGHER MOLECULAR WEIGHT → H_2S H_2Te ARE ALL GASES. The strong H-bond (between H and O) responsible for this.

2. WATER HAS HIGHEST DENSITY at 4°C, not 0°C SO ICE IS LIGHTER THAN WATER, FLOATS. SO AQUATIC LIFE IS PRESERVED. Oceans do NOT ALL FREEZE. RIGHT THROUGH

3. WATER HAS HIGH SPECIFIC HEAT and LATENT HEAT. Difficult to evaporate water! 550 kcal/kg. MUCH HIGHER THAN OTHER LIQUIDS! HIGH specific heat KEEPS EARTH TEMP. UNIFORM. NO violent fluctuations to destroy life

4. GOOD SOLVENT; dissolve almost everything. CAN CARRY NUTRIENTS. WE ARE MOSTLY WATER !

BOTH JWST and TESS, in TANDEM

TO ANALYSE STARLIGHT FILTERING

THROUGH EXOPLANET ATMOSPHERES

WHICH MOLECULES ARE UNIQUE TO

LIVING SYSTEMS ?

O_2 ROLE AS

BIOSIGNATURE DEBATED, AS IT CAN

BE PRODUCED GEOLOGICALLY WHEN

OXIDES HEATED UP. EG. VIKING

LANDER, FALSE ALARM. H_2O_2 decomposed

AGAIN TGO, TO LOOK FOR SOURCE

OF MARTIAN METHANE MYSTERY

(10 ppb detected) ABIOLOGICAL PROD.

SINGLE BIOSIGNATURE GAS COULD

NEVER BE SUFFICIENT TO DISCERN LIFE

SMALL SMELLY MOLECULES LIKE METHYL CHLORIDE, (PRODUCED BY ALGAE OR MARINE BACTERIA), METHYL BROMIDE (produced by SEAWEED AND PETROL SMELLING ISOPRENE (made by TREES) OR DIMETHYL SULPHIDE COULD REVEAL PRESENCE OF ALIEN ORGANISMS IMPRINTING THEIR SPECTRAL SIGNATURES

TEAM FROM CARL SAGAN INST. COLLECTING SPECTRA FROM ALGAE, etc. THAT COULD RESEMBLE VEGETATION on ALIEN PLANETS

SARA SEAGER et al, LUMP ALL BIOSIGNATURES INTO CATEGORIES. (arxiv. org. /abs / 1309. 60147).

SIMULTANEOUS DETECTION, FOR INSTANCE OF METHANE, METHYL CHLORIDE and DIMETHYL SULPHIDE, in an ATMOSPHERE EXTREMELY DIFFICULT TO EXPLAIN FROM GEOCHEMICAL PROCESSES. Seager's team have hunted down spectra for several thousand OF these small molecules (FOR POSSIBLE MATCH WITH EXOPLANET SPECTRAL SIGNATURE ALSO WAYS IN WHICH OXYGEN COULD BE MADE ON A LIFELESS WORLD have been CATALOGUED (astrobiology.doi.org/6qn)

Seager, Bains and Petrowski have created a LIST OF every CHEMICAL WITH SIX OR LESS ATOMS, LINKING elements like C, P, O, N, S and H, the most abundant elements of life!

CHEMICAL ELEMENTS DOMINATING LIVING Systems

WE ARE MOSTLY :

C N O H

A 70 kg. person, made up of

16 kg. C, 43 kg O 7 kg H, 1.8 kg N

(CH_2O → 50 kg, 70% of carbs!)

(CNO H cycle important also in STARS

Also Ca 1.2 kg, Si 1 g. Fe 4 gm

0.8 kg P 0.15 kg S

(Si → 1/3 as abundant as C in universe.

Next generation SPACE TELESCOPES (eg - JWST), capable of detecting biosignatures from LIGHT scattered by EXOPLANETS. SMALL FRACTION OF STELLAR LIGHT (from host star) that scatters of the planet could contain INFORMATION about POSSIBLE existense of LIFE on THESE WORLDS.

Eg. BOTH HUBBLE and SPITZER, have found evidence for CO_2 and H_2O in atmospheres of several GAS GIANT exoplanets as they TRANSIT in FRONT of their HOST STARS. These moleculer absorb LIGHT of distinct IR wavelengths and THIS is Revealed as DARK LINES IN THE STARLIGHT spectrum, filtered through EXOPLANET ATMOSPHERE.

PRESENT INSTRUMENTS NOT YET sensitive TO SEE BIOSIGNATURES IN smaller ROCKY WORLDS (LIKE EARTH). AS FAR AS EARTH IS CONCERNED, POT. BIOSIGN. IS O_2 (or OZONE) as it is abundant in atmosphere and copiously produced by PLANTS and photosynthesizing MICROBES.

JWST can detect O_2 on Earth-like planets in nearby stars.

TPF could be sensitive to spot O_2 RICH planets IN DISTANT STARS, even if planet not TRANSITING AS DETECTORS CAN SEE LIGHT REFLECTED FROM SURFACE. TPF could sight so many systems that it has good chance of honing on O_2 RICH worlds. On a near orbit 'HOT PLANET', water could be broken into H_2 and O_2, so oxygen need not ORIGINATE FROM LIVING systems. HOWEVER on WATER PLANETS, presence of O_2 difficult to explain without presence of LIFE.

GIANT GROUND BASED TELESCOPES LIKE TMT could DETECT, CIRCULARLY POLARISED light REFLECTED OF LIVING MATTER, like LEAVES, PLANTS, or BACTERIAL COLONIES (to the level of the expected POLARS. OF A FEW PER CENT

JUST LYING IN HABITABLE ZONE, ONLY indicates LIQUID WATER can EXIST.

IT DOES NOT GUARANTEE THAT PLANET IS SUITABLE FOR LIFE. PLANET SHOULD BE IN THE RIGHT SIZE RANGE, between 0.3 to 3 EARTH MASS (Below that, atmosphere and water would 'dance off' into space and above that, it would be TOO THICK. THICKNESS OF CRUST and MANTLE (regulating MANTLE CONVECTION, and TEMP.), and PRESENCE OF PLATE TECTONICS also MATTER. IF OUR CRUST WERE A FEW METRES HIGHER, MOST OF O_2 WOULD HAVE BEEN absorbed. IN SHORT, MANY GOLDILOCKS FACTORS INVOLVED. PLANET MUST ALSO START OUT WITH RIGHT INTERNAL TEMP. and GRADIENTS WITH self-regulation [Korenaga, et al 2017 Science Advances). IF, Internal Temp. of Earth, were not within certain range, OCEANS and CONTINENTS may not exist. LARGE MOON and its correct distance also matter! STABILITY OF ROT. AXIS, TIDES, ~~etc~~.

HYDROGEN SULPHIDE (H_2S)

DETECTED ON URANUS !

GEMINI NORTH TELESCOPE, FOUND H_2S MOLECULES IN DEEP ATMOS. OF URANUS. DIRECT DETECTION OF MOLECULE AT 0.4 – 0.8 PPM CONCENTRATION AS ICE IN CLOUD TOPS MORE H_2S THAN AMMONIA. NH_3

ALSO ESTIMATE OF CONC. REQUIRED TO PRODUCE ROTTEN EGG SMELL !

ET GARBAGE CAN PRODUCE H_2S IN EXOPLANETS !

UNUSUAL COMPOUNDS LIKE CHLOROFLUORO chemicals (AEROSOLS), THOSE PRODUCED BY DECAYING PLASTIC (EARTH, NOW A PLASTIC PLANET, TEN MILLION TONS/year DUMPED IN OCEANS etc.) ARE GIVEAWAY INDICATORS OF TECHNOLOGY.

E-WASTE, SEVERAL TOXIC COMPOUNDS INVOLVING RARE EARTHS, etc, MOBILE PHONES ASSOCIATED WITH SEVERAL DOZEN TOXIC POLLUTANTS.

NANOTECHNOLOGY → UNIQUE CHEMICALS

CO, NO, NO_2 → Vehicle pollution. SPECTRO CHEMICAL SOCIOLOGY!

ASTROCHEMICAL SIGNATURES OF 'ADVANCED' ET, TECHNOLOGY. APOCALYPSE?

MARTIAN METHANE MYSTERY

CH_4 DETECTED AT CONC. OF 10 ppb. EXOMARS, TGO, SENSORS FIRST DEPLOYED (LAST WEEK) TO DETERMINE WHETHER, SOURCE IS GEOLOGICAL OR BIOLOGICAL. IF TRACES OF CH_4 FOUND MIXED WITH COMPLEX ORGANIC MOLECULES STRONG SIGN OF BIOLOGICAL ORIGIN. IF MIXED WITH GASES LIKE SO_2, WOULD SUGGEST GEOLOGICAL SOURCE. BIOLOGICAL CH_4 CONTAINS LIGHTER C ISOTOPE. TGO SENSITIVE TO 0.1 ppb, of CH_4.

SEARCH FOR METHANE POCKETS.

CURIOUSITY FOUND CH_4 WHERE IT LANDED. ! ATMOS. CH_4, BREAKS UP IN PRESENCE OF SOLAR UV RADIATION CONTINUED PRESENCE SUGGESTS SOURCE

IF BIOLOGICAL : 2 SCEANORIOUS.

LONG EXTINCT MICROBES HAVE LEFT METHANE TO SLOWLY SEEP TO SURFACE OR LIFE COULD STILL BE CLINGING UNDER SURFACE. EVEN IF CH_4 PRODUCED BY GEOCHEMICAL MEANS IT WOULD INDICATE LIQUID H_2O BELOW SURFACE. ON EARTH OLIVINE MINERAL REACTS WITH H_2O TO PRODUCE METHANE

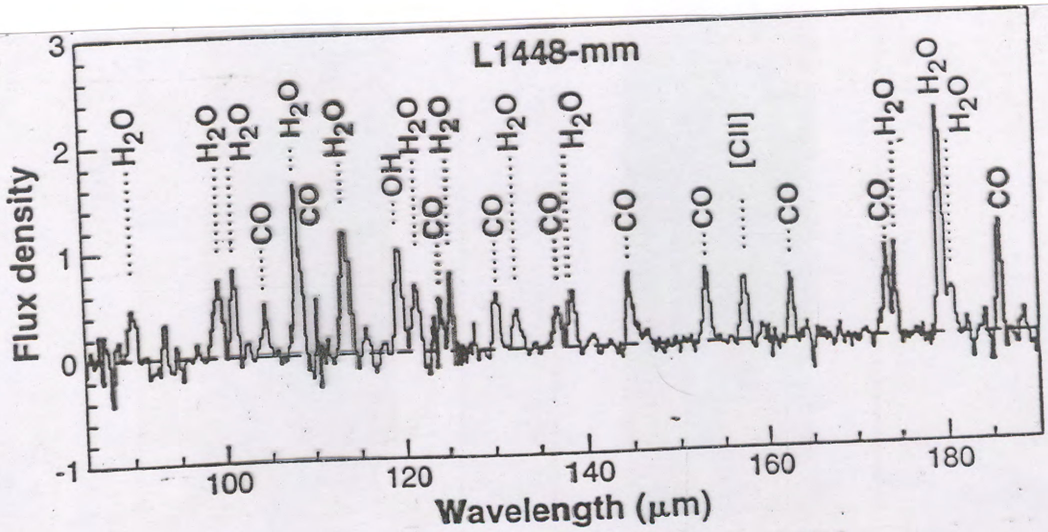
WATER VAPOUR HAS AN EXTREMELY RICH SPECTRUM FROM SUB. MM. TO NEAR IR. CAUSED BY WIDE RANGE OF ROTATIONAL AND VIBRATIONAL EXCITED STATES. MAKES IT A VERY EFFECTIVE COOLANT as MANY CHANNELS ARE AVAILABLE FOR EMITTING PHOTONS AFTER COLLISIONS, CONVERTING THERMAL ENERGY TO RADIATION. H_2O TRANSITIONS AT 539 microns excited at TEMPS. AS LOW AS 40°K.

ISO → FIRST DIRECT OBSERVATION OF WATER EMISSION IN SOLAR TYPE PRECURSORS. SPECTRUM FROM 100 TO 200 microns IN ONE PROTOSTAR

DOMINATED BY STRONG LINES OF WATER AND CO. LINE EMISSION FROM OH and IONISED C ALSO SEEN.

NISINI, et al AA 350, 529; 360, 297

WRIGHT et al AA 358 659.



GAS PHASE INTERSTELLAR AND CIRCUMSTELLAR MOLS

2 ATOMS

H_2, CH, CH^+, NH, OH

HF, HCl, C_2, CN, CO

CSi, CP, CS, NO, NS

OS, $NaCl$, KCl, AlF, $AlCl$

PN, SiN, SiO, SiS, CO^+

SO^+

3 ATOMS

H_3^+, CH_2, NH_2, H_2O, H_2S

C_2H, HCN, HNC, HCO, HCO^+

HOC^+, HN_2^+, HNO, HCS^+, C_3

C_2O, C_2S, SiC_2, CO_2, N_2O

SO_2, OCS, $MgCN$, $MgNC$, $NaCN$

4 ATOMS

NH_3, H_3O^+, C_2H_2, H_2CO, H_2CN

$HCNH^+$, H_2CS, C_3H, C_3N, $HCCN$

$HNCO$, $HOCO^+$, $HNCS$, C_3O

C_3S

5 atoms

CH_4, SiH_4, H_2C_3, CH_2CO, CH_2NH

H_2COH^+, CH_2CN, NH_2CN, $HCOOH$

C_4H

C_4Si, HC_3N, $HCCNC$, C_5

6 atoms

C_2H_4, CH_3OH, CH_3SH, CH_3CN, CH_3NC

NH_2CHO, H_2C_4, HC_2CHO, C_5H

C_5N

7 atoms

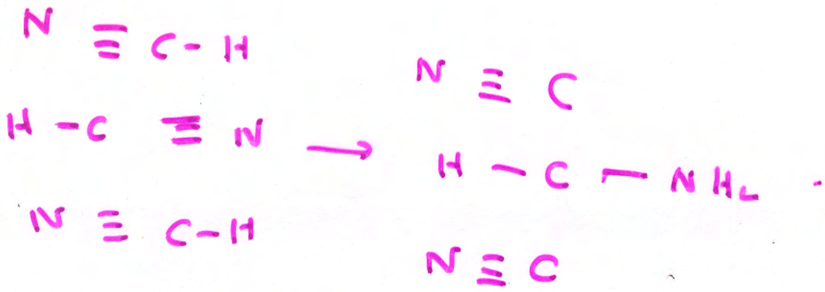
CH_3NH_2, CH_3CCH, CH_3CHO, CH_2CHCN

C_6H, HC_5N

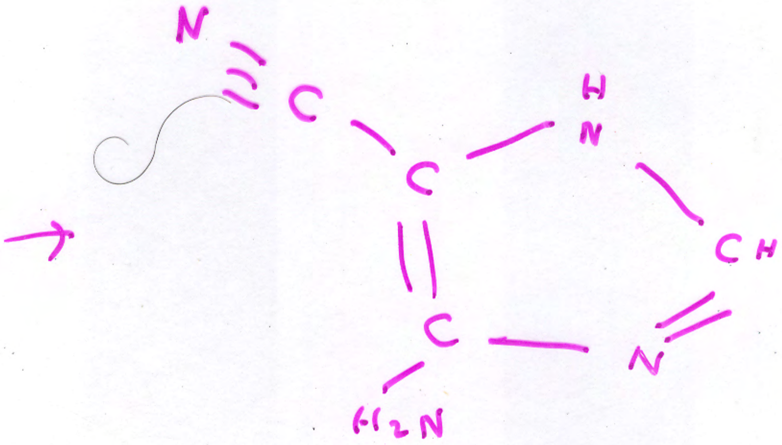
8 atoms

C_2H_5OH, C_2H_5CN, C_8H

HCN to Adenine



amino malonitrile



amino-cyanomidazole

5 HCN's give rise to Adenine

THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 134:319–321, 2001 June

THE MILLIMETER- AND SUBMILLIMETER-WAVE SPECTRUM OF GLYCOLALDEHYDE (CH_2OHCHO)

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ABSTRACT

The simplest monosaccharide, glycolaldehyde (CH_2OHCHO), has recently been detected toward the Galactic center in the source Sgr B2(N) at five frequencies from 71–104 GHz. None of the individual lines used in the detection had been measured previously in the laboratory; rather, their frequencies were predicted based on lower frequency measurements. We have now recorded and analyzed many new rotational transitions of glycolaldehyde through 354 GHz using two spectrometers. Lines through 48 GHz in frequency were measured with a spectrometer that uses Stark modulation, while the higher frequency transitions were measured with a FASSST (Fast Scan Submillimeter Spectroscopic Technique) apparatus. Analysis of the data has allowed us to confirm the interstellar identifications and to predict the frequencies of many additional lines not measured in the laboratory.
Subject headings: ISM: molecules — methods: laboratory — molecular data — radio lines: ISM
On-line material: machine-readable tables

1. INTRODUCTION

Glycolaldehyde (CH_2OHCHO), an isomer of methyl formate and acetic acid and the simplest monosaccharide, has recently been detected toward the Galactic center cloud Sgr B2(N) (Hollis, Lovas, & Jewell 2000). Based on previous studies of molecular abundances toward this source with interferometric techniques, glycolaldehyde probably exists in a small object known as the "Large Molecule Heimat" (LMH; Snyder 1997). The LMH is a hot molecular core about 0.1 pc in diameter, in which a variety of hydrogen-rich (saturated) organic molecules, such as methanol, methyl formate, vinyl cyanide, and ethyl cyanide have already been detected (Snyder 1997; Pei, Liu, & Snyder 2000). It is generally thought that the saturated molecules in hot cores are synthesized at least partially on interstellar dust grains in a previous low-temperature era (Brown, Charnley, & Millar 1988; Millar, Herbst, & Charnley 1991). Unlike low-temperature ion-molecule chemistry, which leads invariably to unsaturated (hydrogen-poor) species (Lee, Bettens, & Herbst 1996), surface chemistry can produce saturated species such as water, ammonia, methane, and methanol via successive hydrogenation reactions with atomic hydrogen (Hasegawa, Herbst, & Leung 1992). For example, methanol is probably formed from CO by the following sequence of surface reactions (Charnley, Tielens, & Rodgers 1997):

$$H + CO \rightarrow HCO\ , \qquad (1)$$

$$H + HCO \rightarrow H_2CO\ , \qquad (2)$$

$$H + H_2CO \rightarrow H_3CO\ , \qquad (3)$$

$$H + H_3CO \rightarrow CH_3OH\ , \qquad (4)$$

despite the fact that reactions (1) and (3) possess at least some activation energy.

At a low temperature (≈ 10 K), most of the molecules produced on dust grains remain in the condensed phase and form large mantles, perhaps 100 monolayers in thickness (Ehrenfreund & Schutte 2000). During the process of star formation, however, the dust grains in the vicinity of the young stellar object can be heated sufficiently to lose their mantles, changing the molecular composition of the gas phase dramatically. The picture is not a static one since the molecules released into the gas phase can then undergo a gas-phase chemistry at the prevailing temperatures of 100–300 K for the $\approx 10^5$ yr lifetime of the hot core.

Two types of models have been used to study the chemistry of hot cores. In one, the grain surface chemistry is ignored and initial gas-phase abundances are assumed following the period of mantle evaporation such that the final gas-phase abundances best fit the observed data (Charnley, Tielens, & Millar 1992). In the second, the gas-phase and grain chemistries of the cold ambient interstellar cloud are followed, and the material that evaporates into the gas when temperatures increase is determined by the chemistry of the earlier cold era (Caselli, Hasegawa, & Herbst 1993). In both types of models, the current picture is one in which more complex species are produced mainly from the precursor molecule methanol via gas-phase ion-molecule, radiative association, and dissociative recombination reactions. Although gas-phase syntheses of molecules such as methyl formate have been suggested (Millar, Herbst, & Charnley 1991), the synthesis of glycolaldehyde is currently unknown. Moreover, it is not obvious that methanol is the most complex species that is released into the gas with the general evaporation of grain mantles. Indeed, it is quite possible that more complex species such as glycolaldehyde are themselves formed on grains. More work is clearly needed to understand the syntheses of the saturated species found in hot cores.

THE ASTROPHYSICAL JOURNAL, 574:L167–L170, 2002 August 1

THE SYNTHESIS OF BENZENE IN THE PROTO–PLANETARY NEBULA CRL 618

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ABSTRACT

We show that the physical conditions in CRL 618 are such that efficient formation of benzene, C_6H_6, occurs. A combination of high temperatures, high densities, and high ionization rates drives an efficient ion-molecule chemistry involving condensation reactions of acetylene and its derivatives, rather than reactions involving atomic hydrogen, as was suggested for the interstellar synthesis of benzene. We find a column density of benzene within a factor of 2 of that observed providing that the material is trapped in a long-lived reservoir of gas in the disk around CRL 618. We note that the chemistry can give rise to other carbon chain molecules as well as a large abundance of benzonitrile, C_6H_5CN.

Subject headings: astrochemistry — stars: AGB and post-AGB — stars: individual (CRL 618)

1. INTRODUCTION

Benzene, C_6H_6, is the smallest of the cyclic aromatic molecules. It is abundant on Earth (in petrol, plastics, detergents, etc.) and also more widely in the solar system (in the atmospheres of Jupiter and Saturn, for example) but until recently was unknown in the further reaches of the universe. It is difficult to detect, in that its emission lies in the infrared regime and is not directly observable from the ground. One of the many successes of the *Infrared Space Observatory* (*ISO*) was the detection of benzene in the proto–planetary nebula (PPN) CRL 618 (Cernicharo et al. 2001b). The detection of benzene in this object is significant because it heralds the beginning of an astrochemistry that is not solely based on linear carbon molecules and small species. It also may prove to be the first step to the formation of polycyclic aromatic hydrocarbons, which are thought to be responsible for unidentified infrared bands and diffuse interstellar bands. Furthermore, understanding the formation of benzene and a chemistry in which rings form readily may eventually help us to understand the formation processes behind prebiotic molecules. Here we present a gas-phase chemical model of CRL 618 in which we show that efficient benzene formation is related to a high flux of ionizing radiation. Such a flux may have occurred early in the history of the solar system.

CRL 618 is a carbon-rich PPN (rather than oxygen-rich) with high-velocity outflows, with speeds of up to 200 km s^{-1}, which are constrained by a disk, with an angular size of about 1″, of hot (>200 K), dense (~10^7 cm^{-3}) gas (Martín-Pintado et al. 1995). It exhibits a complex chemistry and is in transition from the asymptotic giant branch (AGB) to the planetary nebula (PN) phase of stellar evolution. This transition is poorly understood but is thought to occur rapidly, probably in less than 1000 yr, and is important in determining the varied morphologies observed in PNs as compared to spherically symmetric stars. In addition, this transition may help determine the nature of the material returned to the interstellar medium as the star approaches the end of its life.

2. CHEMICAL MODEL OF CRL 618

To date, over 50 molecules have been detected in circumstellar envelopes (Olofsson 1996), mostly in the carbon-rich AGB star IRC +10°216 and some 122 in the interstellar medium in general (A. Wootten 2002;[1] as of April 2002). These range from simple diatomic molecules, like molecular hydrogen, H_2, and carbon monoxide, CO, through to the 13-atom linear carbon chain, $HC_{11}N$. In addition to C_6H_6, *ISO* has also been used to detect several other complex species in CRL 618, including C_4H_2, C_6H_2, C_2H_4, CH_3C_2H, and CH_3C_4H (Cernicharo et al. 2001a, 2001b). More surprisingly, emission from H_2O has also been detected by *ISO* (Herpin & Cernicharo 2000) despite the fact that, normally, water is detected only in oxygen-rich environments. While H_2O has also been detected in IRC +10°216 (Melnick et al. 2001), where it is explained as due to the breakup of cometary bodies, the abundance of water in CRL 618 is too large for this to be the case. Instead, it is likely that water is the result of high-temperature shock chemistry driven by the interaction of the outflow from the central star with the ambient gas. Benzene has not been detected in IRC +10°216.

We have investigated benzene formation quantitatively by using a detailed chemical kinetic model that involves 3880 reactions among 407 species consisting of the six elements: H, He, C, N, O, and S. This model has been previously used to model the chemically rich carbon star, IRC +10°216 (Millar, Herbst, & Bettens 2000). Table 1 lists the initial fractional abundances adopted at the inner radius. To describe the physical conditions in CRL 618, we have used data taken from model fits to *ISO* observations in Herpin & Cernicharo (2000). The hot (30,000 K) central star provides a UV flux of 2×10^5 times the ambient interstellar UV flux, G_0. We model the molecular gas as a shell with a temperature of 250 K at an initial inner radius of 10^{14} cm that drifts away from the central star at a velocity of 1 km s^{-1}; the low velocity simulates the presence of a long-lived reservoir of gas in the disk around CRL 618. A similar

SEARCHING SUITABLE ATMOSPHERES AROUND EXOPLANETS

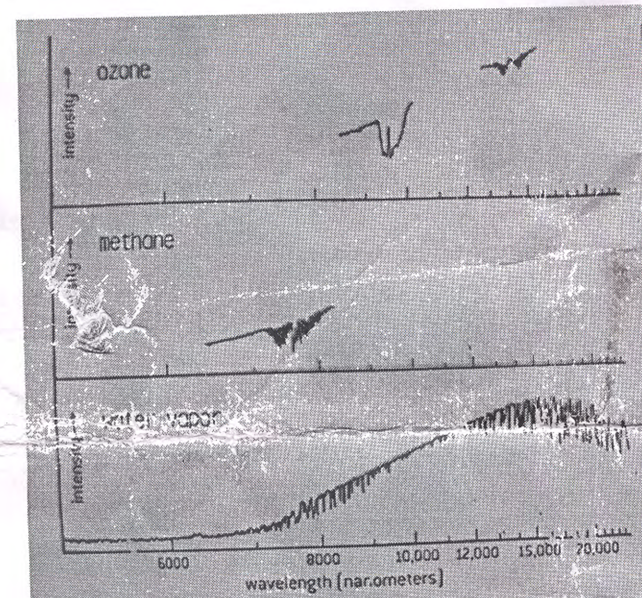
Definitive detection of an atmosphere around an Earth like exoplanet known as GJ 1132b which is 1.4 times the earth's size and hardly forty light years away has been recently reported. It orbits the red dwarf star GJ 1132. It is the first time an atmosphere has been detected on a planet with a mass and radius very similar to the Earth. The GROND imager of the 2.2 m ESO telescope in Chile was used to observe the planet in seven different wave length bands simultaneously. The slight decrease in brightness of the planet's dim host star was measured as the planet's atmosphere absorbed some the star light when the planet passed directly (transited) in front of the star.

An observer on Earth would see the planet transiting (passing directly in front) the parent star every 1.6 days and in the process blocking the stellar light. From the fraction of starlight blocked astronomers can deduce the planet's size (the size of the red dwarf star is well known from stellar models). Presence of an atmosphere makes the planet opaque at a specific IR wavelength but transparent at the other wavelength.

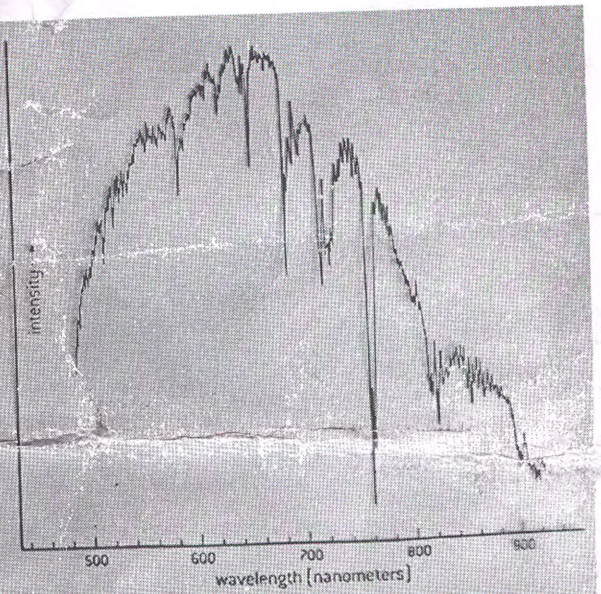
It has been claimed that an atmosphere rich in water and methane could explain the current observations of this particular planet. One possibility is that of a 'water world' with an atmosphere of hot water vapour or steam. Orbiting close to the red dwarf host the planet would be warmer than the Earth. One question is whether such an atmosphere has been sustained for billions of years. As M dwarfs constitute the majority of stars and if GJ 1132b is typical the implications may be that preconditions for life (the existence of water, methane etc.) could be common in the universe.

Another recent discovery with the Kepler space telescope has been the discovery of a Venus like planet orbiting yet another dim red dwarf, Kepler-1649, orbiting it every nine days. This tight orbit implied that the radiation flux on the planet from its host star is more than twice the solar flux on Earth and is comparable to the sunlight intensity on Venus. Would it also have an atmosphere similar to Venus with a runaway greenhouse effect? As we saw in the previous newsletter, there are M dwarfs which host several Earth like planets in orbits that would place these planets in the Star's habitable zone.

What kind of atmospheres around exoplanets could be suggestive of the possible existence of life on them? Astronomers would be excited if they see a planetary atmosphere with water vapour, ozone (which implied presence of substantial oxygen and shielding from ultraviolet) and possibly methane (which is produced profusely on Earth as a result of biological activity). Indeed the spectra of Earthshine (i.e. Earth shining as a celestial object reflecting sunlight) shows clearly presence of all these three constituents (see picture). Especially if the planet is also in the star's habitable zone the presence of such an atmosphere could indicate the presence of life. The James Webb space telescope scheduled to be launched next year (2018) is expected to search for such spectral signatures.



LIFE'S SPECTRAL SIGNATURE will likely consist of a mixture of ozone, methane, and water vapor. The calculated spectra here show the effects of these trace gases on the thermal spectrum of an alien Earth.



THE SPECTRUM OF EARTHSHINE clearly shows molecular oxygen (the lines near 690 and 760 nanometers) and water vapor (the band between 710 and 730 nanometers) superposed on the solar spectrum.

Biomolecules that could provide unique signatures of alien life

Hitherto Astrobiologists have focused their attention on some key molecules (like water vapour, methane or ozone, etc.) that could show up in alien atmospheres (of exoplanets) as signs of life and have made efforts in planning how to interpret them.

Two forthcoming space missions, the James Webb Space telescope scheduled for launch in 2018 and the Transiting Exoplanet Survey Satellite (TESS) scheduled for 2017 will work in tandem to analyse starlight filtering through many exoplanet atmospheres. The starlight could provide unique signatures of the molecules present in these atmospheres, some of which could be produced by living systems. The debate is to ensure which of these molecules are unique to biological life. Oxygen's role as a good biosignature has been debated as it can also be produced geologically (when oxides are heated up). Some also holds for methane.

Observations of a single biosignature gas could never be sufficient to discern its origin. Biochemist William Bains feels there is no limit to what sort of gas life can produce. Small smelly molecules like methyl chloride (produced by marine bacteria or algae), methyl bromide (produced by seaweed) and petrol smelling isoprene (made by trees) or dimethyl sulphide could reveal the presence of alien organisms by imprinting their spectral signature on starlight filtering through exoplanet atmospheres.

A team from Carl Sagan Institute (at Cornell) is collecting spectra from algae and other organisms that could resemble 'vegetation' on alien planets. Meadow's team at VPL is simulating exoplanet atmospheres containing biosignature gases to predict host candidates. Sara Seager and colleagues lump possible biosignatures into categories (arxiv.org/abs/1309.6014). They start from basic chemistry to expand all possible biosignatures. Simultaneous detection, for instance, of methane, methyl chloride and dimethyl sulphide in an atmosphere would be extremely difficult to explain from geochemical processes.Seager's team have hunted down spectra for several thousand of these small molecules (for possible match with exoplanet spectral signatures).Also ways in which oxygen could be made on a lifeless world have been catalogued (astrobiology.doi.org/6qn).

Seager, Bains and Petrowski have created a list of every chemical with six or fewer atoms linking elements like C, P, O, N, S, and H, most abundant elements of life. It would indeed be exciting if in future such unique signatures actually show up in exoplanet atmospheres, perhaps providing unambiguous chemical evidence for alien life.

Detectability of bio-signatures on exoplanets

The next generation of space telescopes could be capable of detecting 'bio-signatures' from the light scattered by exoplanets. The small fraction of the stellar light (from the host star) that scatters off the planet could contain information about the possible existence of life on these worlds.

As it is, both the Hubble and the Spitzer space telescopes have found evidence for carbon-dioxide and water vapour in the atmospheres of a couple of gas giant exoplanets as they transit in front of their host stars. These gas molecules absorb light of characteristic (IR) wavelengths and this is revealed as dark lines in the starlight spectrum which has been filtered through the exoplanetary atmosphere.

However the present instruments are not yet sensitive enough to see bio-signatures (evidence for life) in smaller rocky worlds like the Earth. For instance as far as Earth is concerned, a potential bio-signature is oxygen (or ozone) as it is abundant in the terrestrial atmosphere and moreover is copiously produced by photosynthesizing microbes as well as plants.

The infrared James Webb Space Telescope (JWST), to be launched in 2019 can detect oxygen present in Earth like planets in nearby stars, if such planets happen to transit their host stars. The proposed Terrestrial Planet Finder (TPF) which may be launched in 2020's could be sensitive enough to spot oxygen rich planets in distant stars, even if the planets are not transiting, as the detectors could see light reflected from planet's surface.

The TPF would sight so many systems that it has a good chance of honing on oxygen rich worlds. Just detection of oxygen would not guarantee that life is present, just as detection of water rich planet also does not ensure life is necessarily present. For instance on a near orbit 'hot' planet, water could be broken into hydrogen and oxygen does not necessarily originate from living systems. On water planets, presence of oxygen would be difficult to explain without presence of life. Giant ground based telescopes with proposed mirrors 30 meters across (like the TMT) could detect circularly polarized light reflected off living matter like leaves, plants or bacterial colonies (to the level of the expected polarization of few percent).

Does being in a habitable zone guarantee that a planet is suitable for evolution of life?

We point out that simply lying in the habitable zone of a star does not guarantee that a planet is suitable for life. It only indicates that water can exist as a liquid increasing the chance of an earth type of life. The thickness of the crust and mantle which regulates mantle convection and temperature (and presence of plate tectonics) also matter.

The planet should be in the right size range, between a third to three times Earth mass. Below that the atmosphere and surface water would dance off into space and above that, the atmosphere will be too thick. If our crust were a few meters higher, most of the oxygen would have been absorbed. In short there are many Goldilocks factors involved. Not only the porridge (liquid and water) but many other things have also to be just right.

A new study by researchers at Yale University geology department (Korenagar etal, Science Advances, 2016) supports this. The planet must also start out with the right internal temperature and gradients with self regulation for mantle convection. Such self-regulating mechanisms and planetary Habitability are connected. If the internal temperature of Earth was not in a certain range oceans and continents may not exist (we also know that if the moon were half the distance, tides would submerge all the continents). The study also suggests that such self-regulation is unlikely for Earth like planets. In this connection we recall a book published some years back by P C W Davies.

The Goldilocks Enigma: Why is the Universe just right for life?

Paul Davies, Allen Lane 2006, published in the US in April 2007 as Cosmic Jackpot (Houghton Mifflin).Douglas Adams in the Hitchhiker Guide to the Galaxy asked about life, the Universe and Everything. The issue has been time and again dismissed anthropically (including by string theorists faced with a plethora of possible universes, if the conditions in our world (universe) were not just right we won't be around to ask these questions. Does the multiverse contain an infinite number of universes?

Davis suggests that 'biofriendliness' of the universe may be due to some undiscovered 'life principle' built into the laws of physics from the beginning that constrained the Universe to produce life. He also elaborates on John Wheeler's idea that conscious observers bring about the Universe they find themselves in by the very act of observing it, virtually dragging it out of all possible quantum superpositions. In an earlier issue of newsletter, some years back we had expanded on Harrison's idea that a super-advanced civilization could have created universes similar or identical to theirs.

One of the inflation pioneers Guth actually wrote a paper (in Phys Letters) about creating a universe in your basement and Harrison follows this up. The idea is that such advanced ET's could clone suitable universes starting from tunnelling of quantum vacuum energy. So we find ourselves in one such universe. This idea is not there in Davis' book which readers may like to read.