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## Long Lived Positronium on Earth's Magnetic Field Confirms Equal Antimatter, Matter Gravity and Intraplanetary Double Helix Radio Waves

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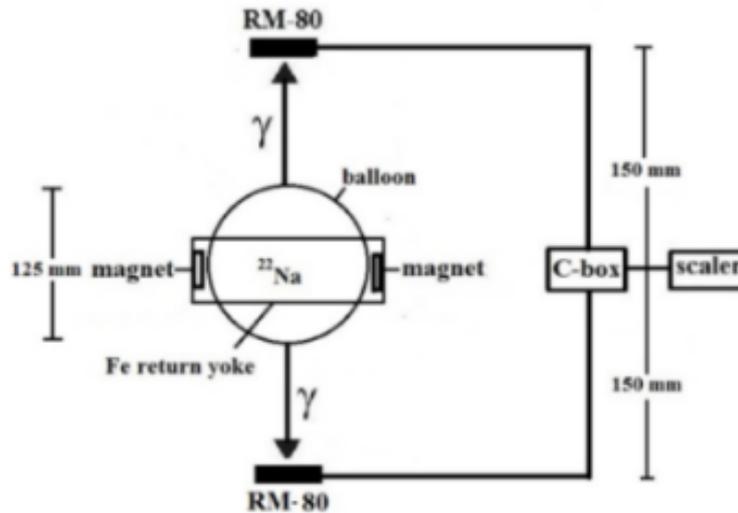
### Abstract

Pair plasma made by  $\beta^+$  ionization of hydrated air in a small trap at Earth's surface in its 0.4G magnetic dipole field forms 21 $\mu$ Hz standing Alfvén waves containing long-lived, outer-well positronium (OWPs). Waves reflect back-and-forth on circular arcs between Scottsdale AZ USA and magnetometer station IPM on Easter Is. Chile. In 150d 13 OWPs are counted on Easter Is. with a 4.3d average lifetime due to OWPs zero magnetic susceptibility. Tunneling lifetimes of these events confirm attractive antimatter-matter gravity. Fast Radio Bursts (FRBS) with 14 and 18min periods result from annihilations of counter-moving OWPs occurring at Chinese/Australian radio telescopes with 44MHz frequency, 27kW power. OWPs reaching Jupiter and its moons from Earth on interplanetary magnetic field lines will annihilate with the plasma. Myr lifetimes of the earliest human data in our planetary system transmitted 4Mkm back to Earth on Alfvén waves may be identified by their radioactivity.

**Keywords:** Magnetic Field, Pair Plasma, Alfvén-Waves, Positronium, Antimatter Gravity, WEP, FRB, Jupiter

### Introduction

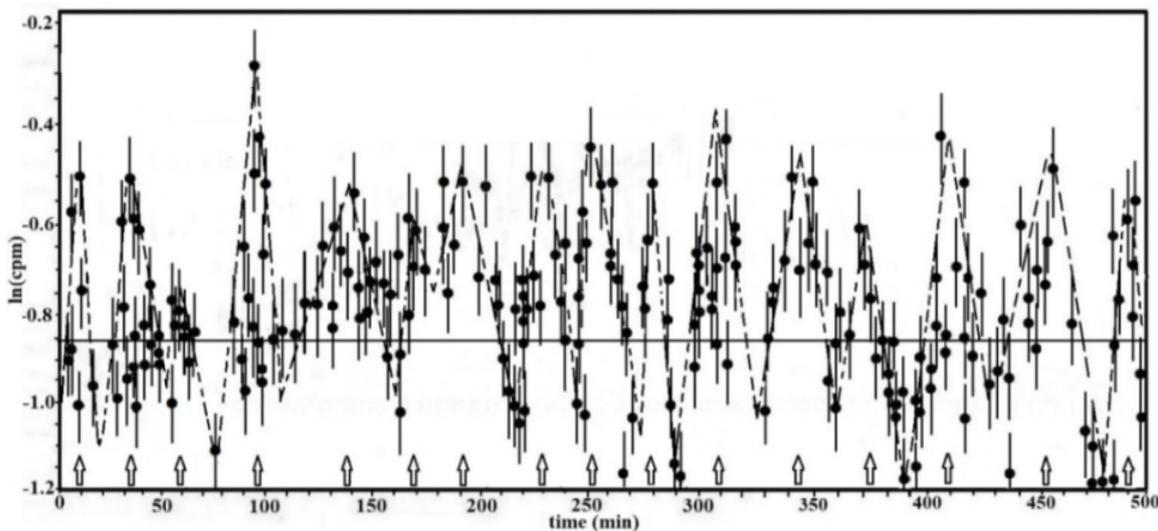
Earlier we reported 4.1, 8.5 and 10.0min  $\gamma$ -ray lifetimes for low energy  $\beta^+$  stopping in a 95G magnetic dipole trap filled with KCl, KBr and KI powders with electric dipole moments  $p \approx 10D$  [1]. In the Born-Oppenheimer approximation Positronium (Ps) binds to molecules with  $p \geq 1.62D$  including water ( $p = 1.87D$ ) [2,3]. Theory explains OWPs formation Two 44mm diameter Aware Electronics RM-80 Geiger counters with 80 $\mu$ m thick mica windows and 55 $\mu$ s dead time viewed a 125mm diameter rubber balloon filled with 5% hydrated air (Fig.1), each 150mm from balloon center subtending a  $5.5 \cdot 10^{-3}$  solid angle fraction [4-7]. A  $9 \pm 2\%$  counter efficiency gave  $\epsilon_{2\gamma} = (5.5 \cdot 10^{-3}) (0.09 \pm 0.02)^2 = 4.4 \pm 1.7 \cdot 10^{-5}$ . A 0.14 $\mu$ Ci  $^{22}\text{Na}$   $\beta^+$  source atop the balloon annihilated 35% of positrons inside the source at a 0.35% rate [8-10]. Two 16 mm diameter NdFeB magnets on ends of a 150mm long iron yoke formed pole face fields of  $B_m = 50G[1+0.0021(75\text{mm})^2] = 641G$ .



**Figure 1: 125mm Diameter Balloon with 25 $\mu$ m Rubber Walls and A 0.14 $\mu$ ci  $^{22}\text{Na}$ , G, RM-80 2.6yr B $^+$  Lifetime Source on Top of the Balloon in a 50g Dipole Field and Two Rm-80 Geiger Counters, Coincidence Circuit and Scaler**

### 50G Dipole Trap Test Results

At Scottsdale, Arizona (32N 112W)  $2\gamma$  coincidence counting started on 10-21-17 for 19d and was completed on 02-04-19 for 9 d. Correcting  $^{22}\text{Na}$  rates to 2017 the average rate was  $\ln(0.43\pm 0.04\text{cpm}) = -0.84\pm 0.09\text{cpm}$  (solid line, Figure 2). A  $300\pm 7\text{cpm}$  singles rate gave a  $2(300\pm 7\text{cpm}) (1\text{min}/60\text{s})^2 (55\pm 10\cdot 10^{-6}\text{s}^{-1}) (60\text{s}/\text{min}) = 0.16\pm 0.03\text{cpm}$  accidentals rate. Including  $0.10\pm 0.01\text{cpm}$  for positron cosmic rays (but not trapped at MeV energy) this agrees with a previously measured coincidence rate of  $\ln(0.28\pm 0.02\text{cpm}) = -1.27\pm 1.20\text{cpm}$  [11]. The Ps capture fraction was  $\epsilon_{\text{cap}} = (0.28\pm 0.02\text{cpm})/(\lambda_0 N_0 \cdot 0.05 \cdot 0.32 \cdot \epsilon_{2\gamma}) = 132\pm 26\%$  that agrees with another gaseous molecular analyses [12].



**Figure 2: The Ln Count Rate in a 50g Magnetic Dipole Field at Scottsdale, Az with a  $32\pm 1\text{min}$  Period and  $\Omega_0 = 3.3\pm 0.1\text{mhz}$  Frequency; (Arrows); (Dashed Lines) Waves and (Solid Line) Average Rate**

### Loss Cones

Fig. 2 shows Alfvén waves first introduced in the classic 1942 MHD discovery paper [13]. Such waves require a pointing magnetic field emerged in a plasma. Counter-rotating electrons and positrons in the plasma collide to form Ps with oscillator widths  $b_x, b_y = 0.7\cdot 10^{-5}\text{cm}$ . Rutherford scattering into the loss cones with  $R_m = 641\text{G}/50\text{G} = 12.8$ ,  $\theta = \sin^{-1}(1/\sqrt{R_m}) = 16.2^\circ$  and  $E = 1\text{keV}$  gave a positron containment time of  $2\text{ns}\{2[\cos(1/\sqrt{R_m}-\theta)]^2 E + (\text{keV})^{3/2}/760 \cdot \ln[2.7 \cdot E + (\text{keV})]\} = 1.5\pm 0.5\text{ns}$  and capture fraction  $\epsilon_{\text{cap}} = [1 - \exp(-1.5\pm 0.5\text{ns}/0.125\text{ns})]/0.05 \cdot 0.32 = 125\pm 62\%$  that agrees with  $132\pm 26\%$  discussed in the previous section [14-17].

### Pair Formation, Decay Rates, Wave Stability

$\delta$ - rays are made in gas by forward Bhabha scattering. The 1 keV  $\beta^+$  yield is  $0.32 \cdot 0.05 \cdot 50\beta^+/\text{cm} = 0.08\delta^-/\beta^+\text{cm}$  (Corson 1938) [18]. The  $\beta^+$  lose 10% in number by recombination and 94% by solid angle for a yield of  $(0.08\delta^-/\beta^+\text{cm})$

$(0.90) (0.06) (0.7\text{cm trap diameter}) = 0.003\text{pairs}/\beta^+ [19]$ . The formation rate is  $0.003\text{pairs}/\beta^+ \cdot \lambda_0 n_0 = 2.8 \cdot 10^5 \beta^+/\text{min}/R_L = (0.037\text{cm})^2 (0.35\text{cm})$  or  $5.6 \cdot 10^6 \text{pairs}/\text{cm}^3 \cdot \text{min}$ .

The OWPs lifetime is  $\tau(\text{OWPs}) = \tau(\text{Ps}) |\Psi_{\text{OWPs}}(0)/\Psi_{\text{Ps}}(0)|^2$ , where the contact densities are  $(0.3989)^2 \text{au}^2$  for OWPs at a pseudo-momenta  $\leq 1 \text{ au}$  and Ps density  $(0.03979/n^6) \text{ au}^2 [6]$ . With  $\tau(\text{OWPs}) = 32 \text{ min}$  and  $\tau(\text{pPs}) = 0.125 \text{ ns}$ , substitution gives  $n = 125$ . The time for Ps (125) in an  $L = 0$  state to emit consecutive photons to the Ps ground state is  $0.6\text{min}$  (Bethe & Salpeter) at an average rate of  $[1 - \exp(-142 \cdot 10^{-9}\text{s})] (125)^3 / 0.6\text{min} = 0.48\text{cpm}$  that agrees with  $0.43 \pm 0.04 \text{ cpm}$  in Figure 2.

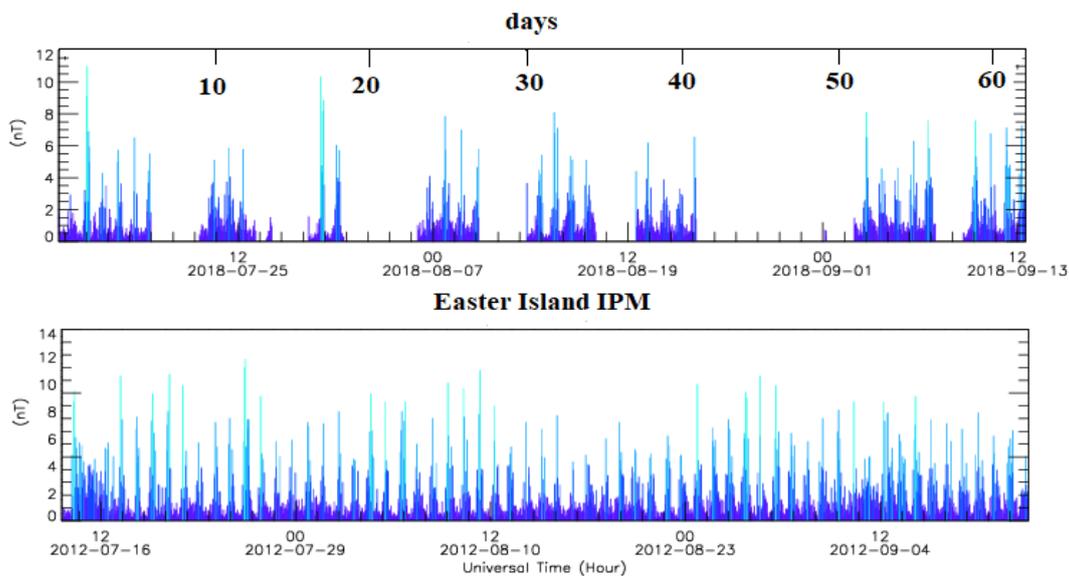
Alfven waves are stable in magnetically confined pair plasma provided (1)  $\omega_p = e\sqrt{(n_{\pm}/\epsilon_0 m)} = 76\text{kHz} > \omega_0$  (2)  $\lambda_D = 69\sqrt{(293/n_{\pm})} = 173 \text{ mm}$  trap diameter (3)  $n_{\pm} \geq 106\text{m}^{-3}$  and (4)  $B_0 > 0.1\text{G}$  [20-23]. All 4 conditions are satisfied. The pair number and density are  $N_{\pm} = (2.8 \cdot 10^5 \beta^+/\text{min}) (500\text{min}) (0.05) (0.32) = 2.2 \cdot 10^6$  and  $n_{\pm} = 2.2 \cdot 10^6 / 1.2\text{cm}^3 = 1.8 \cdot 10^{12} \text{ m}^{-3}$ , significantly less than  $10^{16} \text{ m}^{-3}$  discussed by and in works in progress [24,25].

### Alfven Waves in Earth's Magnetic Field

The dipole magnet was removed to study effects of Earth's dayside 0.4G field. Alfven waves with a  $3.5 \pm 0.5\text{d}$  period,  $\omega_0 = 21 \pm 3 \mu\text{Hz}$  frequency and  $49 \pm 7\text{d}$  RT damping were observed. The count rate was  $\ln(-0.85 \pm 0.05\text{cpm}) (0.08\mu\text{Ci}/0.14\mu\text{Ci}) = 1.37 \pm 0.05 \text{ cpm}$ . Standing Alfven waves follow Earth's dipole field with reflections at Scottsdale and conjugate IPM magnetometer station on Easter Is. The existence of standing waves on Earth was previously confirmed [26,27]. The field distance to Easter Is. from Scottsdale is  $5.3 \cdot 10^6\text{m}$ , or  $1.6 \cdot 10^7\text{m}$  from nearby TUC, 140km SE of Scottsdale [28]. Equatorial Alfven velocities with  $v_A = 200\text{-}1400\text{km/s}$  at  $L=3\text{-}11$  are approximated to  $\ll 1 \text{ km/s}$  at  $L=1$ [29]. Earth's Coriolis Force forms fast (+) and slow (-) circularly polarized waves with  $v^2(\pm) = v_A^2/(1 \pm \Omega/\omega_0)$  [30]. With Earth's rotational frequency  $\Omega = +0.771 \cdot 10^{-4} \text{ Hz}$ ,  $v_+ = 260 \text{ m/s}$  that was close to  $\ll 1 \text{ km/s}$  and  $v_-$  is imaginary. Double-helix pulsar radio wave frequencies cannot be confused with those made on Earth due to their smaller fields [31].

### Magnetograms

The Figure 3 magnetograms were recorded on Easter Is. from 7-15-18 to 9-15-18 with  $^{22}\text{Na}$  (top) and 7-15-12 to 9-13-12 without  $^{22}\text{Na}$  (bottom). Blue/green oscillations are due to ocean surface/tidal waves on Easter Is. We define a ZFL (Zero Field Lifetime) as the time for the field to fall rapidly to zero and slowly return back to baseline. OWPs with diamagnetic susceptibility  $X_D = 0$  create the ZFL = 0 gaps seen in Figure 3.  $\text{N}_2$  gas with  $X_D = -11.938 \cdot 10^{-6}$  fills between the gaps [32]. A 60d scan with  $^{22}\text{Na}$  shows 7 ZFLs centered on 7-22-18(4), 7-27-18(4), 8-06-18, 8-13-1(4), 8-18-18(4), 8-26-18(7+) and 9-09-18(6) with dates/strengths italicized. A longer 150d 7-15-18 to 12-15-18 scan found 13 ZFLs with an average OWPs lifetime of  $4.3 \pm 2.0\text{d}$  and decay probability  $\exp(-13 \pm 4 \cdot 4.3 \pm 2/150) = 0.69 \pm 0.38$ . An important feature of OWPs is that their presence is fundamentally understood with classical physics principles.



**Figure 3:  $^{22}\text{Na}$  magnetograms (top, 2018), w/Na22 : (bottom, 2012), blue/green are surface/tidal waves**

### Geomagnetic Storms

On 8-21-18 a coronal mass ejection (CME) occurred on the Sun, followed on 8-26-18 by the largest geomagnetic storm of 2018 with a 10d long ZFL. GRACE satellite data gave a peak injected neutral kinetic energy density of  $0.5 (4 \cdot 10^{-13}\text{kg}/\text{m}^3) (490\text{m/s})^2 = 4.8 \cdot 10^{-8}\text{J}/\text{m}^3 [33]$ . One OWPs injects a neutral  $\gamma$ -ray energy density of  $(5.6 \cdot 10^{12}\text{pairs}/\text{m}^3 \cdot \text{min}) (10^6\text{eV}/\text{pair}) (1\text{J}/6.25 \cdot 10^{18}\text{eV}) (1440\text{min}/\text{d})$  or  $1.29\text{J}/\text{m}^3$ , leaving  $1.29\text{J}/\text{m}^3 (10^{-2.5})^3 = 1.29 \cdot 10^{-7.5}\text{J}/\text{m}^3$  or 0.52 of CME neutral energy, making it a source of storms. GRACE magnetometers confirm a 180nT field with a 10d decay [34].

This magnetic field was created by Compton scattering of  $\gamma$ -rays created in the upper atmosphere followed by their entry into the lower atmosphere. The average Compton electron energy is  $\sigma_a/\sigma = 3.8 \cdot 10^{-5} \text{cm}^{-1}/(11.3 \cdot 10^{-5}/\text{cm}^{-1})$  (511keV) = 172keV with  $\sigma/\sigma_a$  the total/absorption coefficient [35]. LEO data give  $(10^{2.5} \text{electrons}/\text{cm}^2 \cdot \text{sr} \cdot \text{s})$   $(1.6 \cdot 10^{-19} \text{C}/\text{electron})$   $(R_E = 6.4 \cdot 10^8 \text{cm})^2 (\text{nsr}) = 0.02\text{-}2\text{kA}$  currents around field lines [36]. The Biot-Savart Law for 1kA electrons at a 3km radius 1km above IPM gives a -180nT field. The OWPs wave packet expansion in  $t = 10\text{d}$  was  $\Delta x = \pm 2\sqrt{(\hbar t/2m_e)} = \pm 37 \text{cm}$ , double the OWPs length creating background annihilation oscillations with nearby OWPs [37].

### Antimatter Gravity Barrier Tunneling and WEP

The gravitational attraction of OWPs to Earth can be found using our data. Assuming equal attractive matter-matter and matter-antimatter gravity allowed by Einstein's Weak Equivalence Principle (WEP), an OWPs should feel the maximum attraction of gravity. The Bohr-Sommerfeld quantization rule with reflection at Scottsdale and Easter Is. is  $\int_a^b p \cdot dx/\hbar = 3\pi/2$  ( $n=0$ ) for a tunneling lifetime of  $\exp(-2 \cdot 3\pi/2)$   $(2\pi/21 \cdot 10^{-6} \text{s}) = 24\text{d}$ , exactly one-half of the  $49 \pm 7\text{d}$  round trip damping lifetime [38]. This proves the OWPs electron and positron feel equal downward attractive gravitational forces consistent with WEP. The same result was reported in 2023 in an experiment done at CERN [39].

Large distances permit classical barrier tunneling to be applied [40]. The 648d  $^{22}\text{Na}$  exposure from 7-15-2018 to 4-15-2020 including combinatoric factors give lifetimes of  $640\text{d}/2 \cdot 4 = 80\text{d}$  ( $66 \pm 12\text{d}$ ),  $640/3 \cdot 9 = 24\text{d}$  ( $20 \pm 4\text{d}$ ) and  $640\text{d}/4 \cdot 16 = 10\text{d}$  ( $10 \pm 2\text{d}$ ) with our observations in parentheses. OWPs stability is created by inelastic  $\beta^+$  collisions that bind OWPs electric dipole moments to each other. For example, four OWPs binding to a water molecule give  $p = 4(1.6 \cdot 10^{-19} \text{C})$  ( $R_L = 0.99\text{m}$ ) =  $6.4 \cdot 10^{-19} \text{Cm}$  with binding of  $-4p^2/4\pi\epsilon_0 R_L^3 = -136\text{neV}$ ,  $\ll$  the 4.6neV OWPs ionization energy [4].

### Fast Radio Bursts

From Easter Is. 44MHz double helix Larmor radio waves traveled 12,000km in the southern hemisphere over the Pacific Ocean to the Australian Widefield Array (MWA) radio telescope. These signals are similar in frequency to those observed by satellite and VLA ground telescopes that identified polarized double helix short wave radio signals from a distant galaxy [41]. From 1-3-18 to 3-28-18, 17 Fast Radio Bursts (FRBs) with  $18 \pm 1\text{min}$  period were observed at MWA [42].

Over nearly the same parallel distance in the northern hemisphere from Scottsdale to the Chinese FAST radio telescope, short wave radio FRBs were observed in April-September 2020 with a  $(18.5\text{hr}/79)$   $60\text{min}/\text{hr} = 14 \text{min}$  period [43,44]. On 8-15-19 the  $^{22}\text{Na}$  at Scottsdale was removed, but "orphan" OWPs decayed well into 2020. The equivalent time between direct and reflected annihilations on the Scottsdale-Easter Is. path was  $10^7\text{m}/552\text{m}/\text{s}/2/60\text{s}/\text{min} = 15\text{min}$ . With  $9.3 \cdot 10^7$  telescope pointing gain, the transmitted power to MWA and FAST was 27kW [42]. This is remarkably close to Marconi's 1901 25kW transmission time from Cornwall, England to Newfoundland, Canada.

### Interplanetary Alfvén Waves

Based on recent studies Alfvén waves traveling on an interplanetary magnetic field line from the Sun passing through Earth and intervening plasma would reach Jupiter in a few hours [45,46]. Scaling from the 27kW required on Earth, the power for short wave radio transmission from Earth to Jupiter is 25MW that could be provided by small nuclear reactors.

The present time limit on bulk satellite transportation to Jupiter from Earth is provided by NASA's Europa Clipper that reached Jupiter's moon Europa 4Mkm from Earth in 7 months. At Europa wave-carried OWPs will annihilate in the surrounding plasma with its data teleported to Earth. Detection of annihilation remnants in human PET medical research would allow samples from Jupiter to be compared for dissimilarities in composition [47]. Differences would separate plasma with much longer lifetimes revealing Myr lifetime expected from early human life. Investigations of important minerals will also be possible using robotically controlled satellites. Masses of up to 7,000kg/satellite to replace Earth's supply can be transported back to Earth. A proposal for funding of activities discussed above is in preparation. This work could be integrated into NASA's present Mars program.

### Conclusions

Pair plasma made by  $\beta^+$  on Earth ionizes hydrated air in a small magnetic trap forming 21 $\mu\text{Hz}$  standing Alfvén waves on Earth's 0.4G field line at Scottsdale, AZ. Outer well Ps (OWPs) form and bind to waves that travel in circular paths to conjugate IBM station on Easter Is. in the southern hemisphere. Its magnetometers record strings of average 32cm long OWPs with 47d round-trip damping and 4.3d lifetime. Double-helix pair annihilation can create geomagnetic storms with a 1d, 180nT falloff and slow 10d regrowth. As they pass through the magnetometers OWPs with zero magnetic susceptibility are revealed including their lifetime. Time coincident FRBs of 18 and 14 min are observed by the MWA (26S 116E) and FAST (26N 116E) radio telescopes. Data show that classical tunneling is consistent with equal attractive antimatter and matter gravity, as well as counter-moving OWPs annihilations that create 14 and 18min period FRBs with 44Mz frequency short wave radio waves detected on Earth's opposite side. Alfvén OPs waves traveling to distant planets from Earth on interplanetary magnet fields may reveal secrets of early human life as well as important mineral deposits to replace Earth's supplies over time [48-50].

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