Designing Kepcelis (a chemosynthetic-based planet)

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Abstract

This is a research paper that covers the possibility of having a planet that can depend on chemosynthesis with no source of light, with life thriving there from chemosynthetic organisms and bacteria to a deep oceanic fish that can live on the bacteria and the hydrothermal vent.ging from its physical features, to its biological life and environment, integrating all this together to make Kepcelis.

Introduction

For a planet to be called so in additional to being habitable, it must meet a lot of criterias like its mass must be in a specific range so it can be sufficient and enough to it's self-gravity so it can overcome the rigid bodies that comes near it with similar or smaller size and to be in equilibrium, it's luminosity ,to be in orbit around a sun/star and lastly what differentiate a planet from a dwarf planet is the clearance of the neighborhood near the planet's orbit.chemosynthesis is a process that differs a lot from photosynthesis as it does not depend on sunlight at all, but in chemicals presented in the environment so energy be produced.there are a lot of organisms that depends on it.

Planet-description

After searching a lot around the universe for planets, moons and more that seems to be habitable and seeing why scientists were thinking that life might thrive there, we just needed to take samples to break it with certainty.we gathered a lot of data in building our planet Kepcelis. Chemistry was studied so well to observe the chemosynthesis and chemosynthetic organisms so we can get a suitable environment for our planet.

Kepcelis orbits a red dwarf star with spectral type M. From our planet's characteristics, it has its moon which helps in making our planet's craters and tidal waves that keeps life and the water cycle.

Moon's-characteristics

Number of moons:1
Moon's mass:0.85%
the planets mass ≃$0.85\%\ x\ 1.021212\ x\ 10^{25}$ ≃ $8.680302\ x\ 10^{22}$ kg
Its moon's orbit:56,000 km from the planet's surface

Orbital-characteristics:

Orbital Radius:0.432 AU
Orbital period :129.9 days

Physical-features:

Its mass:1.71 x Earth mass ≃$1.021212\ x\ 10^{25}\ kg$
Its radius:$1.17\ x\ Earth\ radius \simeq 7454.07\ km$
Its gravity: using this equation → $g\ =\ \frac{GM}{r^2} = \frac{6667x\ 10^{-11}\ x\ \ 1.021212\ x\ 102}{7454.07\ x\ 10^{6}} = \ 12\ m/s^2$
Its average temperature : -10 to 80 c (ranges from place to other where its highest at the gate of the hydrothermal vents and lowest at the icy crust/objects)

Core-composition:

As our planet has subsurface ocean and core reach with mineral and many chemical compositions enhancing life there , its soil composition too.
Silicate is the dominant mineral as it makes a stable base for the soil as it help in bending chemicals together acting as a medium for chemical reactions.its soil containing sulfur which is essential for the chemosynthesis in the hydrothermal vents, ammonia, nitrogen and sulfuric acid are present too as they come out of the hydrothermal vents affecting the soil around it and nutrienting the chemosynthetic living organisms, also iron and iron oxide present for the redox resection which is crucial for chemosynthesis. Other elements are there in the soil as magnesium, water and phosphate but with smaller amounts.

Geological-features:

1) **Hydrothermal vents:** the main feature and the primary energy source, may release black smokers (clouds of mineral-rich-water), feeding the chemosynthetic livings
2) **Volcanic activity:** by the tidal force made by the moon, there will be submarine volcanic activity that will provide rocks and minerals crucial for living and contributing to the planet's thermal heat
3) **Ocean current and icy fracture**: due to the tidal forces from the moon , ice fracture will appear causing the release of gasses resulting in recycling it, ocean current helps in distributing the nutrient in the sea and forming plumes creating areas with biological diversity

Soil-composition:

Silicate: the dominant mineral making a stable base by helping in bending chemicals acting as a medium.**Sulfur:**crucial in chemosynthesis**ammonia/nitrogen/sulfuric acid:** nutrienting the chemosynthetic livings.**iron/oxide**:for redox reduction which is crucial for chemosynthesis.**magnesium,water and phosphate:**exist with smaller amounts.

Kepcelis formation:

Kepcelis came to life by a gravitational field that pulled gasses and dust forming its core. There are many theories regarding how it was formed but the strongest one to Kepcelis' formation is the planetary explosion theory which suggests that it was a large celestial object that exploded suddenly forming smaller fragments and debris left that then gathered together creating Kepcelis and its core. This explosion resulted in creating a rich mineral gasses clouds and debrises, its ocean was created from the reaction between hydrogen and this metal filled clouds and fragments, that's why Kepcelis ocean is rich with minerals helping life to thrive there.

Ocean composition:

In the subsurface ocean of Kepecils, various chemical compounds facilitate chemosynthesis, enabling potential life forms to thrive. Here's a detailed breakdown:

1. Key Chemical Compounds

- **Hydrogen Sulfide (H_2S)**:
    - **Percentage**: Approximately 5-10% of the dissolved gasses.
    - **Role**: Serves as a primary energy source for sulfur-oxidizing bacteria.
- **Methane (CH_4)**:
    - **Percentage**: Roughly 1-5%.
    - **Role**: Used by methanogenic archaea and as a substrate for various microbial processes.
- **Ammonia (NH_3)**:
    - **Percentage**: Around 1-2%.
    - **Role**: Acts as a nitrogen source for microbial growth.
- **Carbon Dioxide (CO_2)**:
    - **Percentage**: Estimated at 10-15%.
    - **Role**: Fixed by chemosynthetic organisms, forming organic compounds.
- **Nitrous Oxide (N_2O)**:
    - **Percentage**: Less than 1%.
    - **Role**: Involved in nitrogen cycling and may be utilized by specific microbes.
- **Silica (SiO_2)**:
    - **Percentage**: Varies, often around 5%.
    - **Role**: Provides essential minerals for diatoms and siliceous organisms.
- **Hydrogen (H_2)**:
    - **Percentage**: Approximately 1-3%.

- **Role**: Another potential energy source for hydrogen-utilizing bacteria.

2. Environmental Conditions

- **Temperature:**
  - **Range:** Estimated between -10 to 50 degrees Celsius, influenced by geothermal activity.
  - **Properties:** Varying temperatures create diverse habitats and support different life forms.
- **Pressure:**
  - **Depth**: The ocean could be up to 30 kilometers deep, leading to high-pressure conditions.
  - **Properties:** High pressure may support unique adaptations in marine life.
- **Density:**
  - **Factors:** Influenced by salinity and temperature.
  - **Properties:** A denser ocean may enhance buoyancy and support larger organisms.
- **Hydrothermal Activity:**
  - **Sources:** Similar to Enceladus, active hydrothermal vents could exist.
  - **Properties:** These vents would release mineral-rich fluids, providing energy and nutrients for chemosynthetic organisms.

<u>Atmospheric Layers:</u>

Kepcelis would need an atmosphere with layers to protect life from harmful radiation and regulate temperature. Here's a possible structure:

- **Troposphere** (surface to ~15 km):
  - Contains most of the atmospheric mass and is where weather phenomena occur.
  - Dense with gases like methane (CH_4), carbon dioxide (CO_2), nitrogen (N_2), hydrogen sulfide (H_2S), and traces of water vapor.
  - This layer is rich in gases that facilitate chemosynthesis.
- **Stratosphere** (15 km to ~50 km):
  - Thinner gases with a possible haze layer that scatters light.
  - Contains some aerosols, which provide a weak greenhouse effect to maintain a stable temperature.
- **Mesosphere** (~50 km to ~80 km):
  - A cooler region where meteors burn up.
  - Helps protect the surface from impacts.
- **Thermosphere** (~80 km to ~300 km):
  - Absorbs high-energy radiation and contributes to the stability of lower layers.
  - A small amount of ionization could exist here, producing faint auroras.
- **Exosphere** (above ~300 km):
  - A thin outermost layer, gradually transitioning into space.

Weather System:

Kepcelis would have a unique weather system:

- **Clouds and Precipitation:**
  - Instead of typical water clouds, Kepcelis might have clouds made of methane or ammonia, especially if temperatures are low.

- Precipitation could take the form of methane or ammonia drizzle, contributing to surface chemical diversity.

- **Temperature:**
  - The temperatures would be relatively cold. Average surface temperature could range from -50°C to -10°C.
  - Hydrothermal vents at the ocean floor would create localized hotspots, critical for supporting chemosynthetic organisms.
- **Winds and Ocean Currents:**
  - Winds could be relatively mild due to the planet's denser atmosphere and stable climate.

- Subsurface ocean currents would be driven by heat from hydrothermal vents, circulating minerals and chemicals that support life.

Seasons:

Kepcelis has the physical and orbital characteristics of Kepler-186f, so its seasons would depend on its axial tilt and orbit:

- **Axial Tilt:**
  - If Kepcelis has a similar tilt to Earth's (~23.5°), it would have distinct seasons, though not as pronounced due to the lack of traditional photosynthetic life.
  - With a lower tilt, seasons would be more subtle, affecting temperature slightly but mainly influencing ocean current patterns.
- **Seasonal Cycle:**
  - **Cool Season:** Dominated by lower temperatures, with reduced activity in surface ecosystems but a steady supply of nutrients near hydrothermal vents.
  - **Warm Season:** Slight warming could cause increased methane cloud formation and possibly more active vent regions, leading to higher rates of chemosynthesis.
- **Orbital Period:**
  - If Kepcelis has an orbital period similar to Kepler-186f (around 130 Earth days), seasons would be shorter compared to Earth, leading to quicker changes in the subsurface ocean dynamics and temperature variations.

Overall Suitability for Life:

- **Chemosynthesis-Based Ecosystem:** The presence of hydrothermal vents in the subsurface ocean provides a stable environment for chemosynthetic bacteria and archaea, which thrive by converting chemical compounds like hydrogen sulfide into energy.
- **Stable Climate:** The atmosphere is designed to maintain temperature stability, particularly in the ocean, where life is sustained.
- **Protective Layers:** The atmospheric layers provide protection from radiation and maintain conditions that support chemosynthetic life forms, contributing to a balanced and self-sustaining ecosystem.

This setup provides a balance of stability and variability that supports a diverse range of chemosynthetic organisms, that hypothesized to exist on Kepcelis.

1. Primary Producers (Chemosynthetic Organisms)

Methanogens:

These archaea are key to methane-based ecosystems, converting hydrogen and carbon dioxide into methane through methanogenesis. Found in anaerobic environments like deep-sea hydrothermal vents, they thrive at temperatures of 50°C to 100°C (122°F to 212°F). Methanogens are crucial in providing the base energy for other organisms, ensuring the methane supply for methanotrophic bacteria. They play a critical role in maintaining ecosystem balance by supporting methane-dependent life forms.

Ecosystem Balance: Methanogens are foundational for methane-rich ecosystems, as they produce the primary fuel—methane—that supports various consumers. Without them, the energy flow would collapse, severely affecting the entire food web.

Methanotrophs:

These bacteria utilize methane produced by methanogens as their energy source, converting it into carbon dioxide and water. Methanotrophs exist in methane-abundant areas like hydrothermal vents and can thrive at 20°C to 80°C (68°F to 176°F). They help regulate methane levels in the environment, ensuring a balanced concentration of this potent greenhouse gas.

Ecosystem Balance: Methanotrophs control methane concentrations, preventing excessive buildup, which could disrupt the ecosystem's energy dynamics. Their balance with methanogens ensures that methane production and consumption remain steady.

Sulfur-Reducing Bacteria:

These bacteria reduce sulfur compounds (such as sulfates) to derive energy, producing hydrogen sulfide in the process. They thrive in sulfur-rich hydrothermal environments at temperatures between 40°C and 110°C (104°F to 230°F). These bacteria contribute to the sulfur cycle, which is critical for chemosynthetic ecosystems.

Ecosystem Balance: Sulfur-reducing bacteria drive the sulfur cycle, an essential process for other sulfur-dependent organisms, like sulfur-oxidizing bacteria. Their activity keeps sulfur compounds cycling, supporting energy flows and ecosystem health.

Sulfur-Oxidizing Bacteria:

These bacteria oxidize hydrogen sulfide and other sulfur compounds, producing sulfuric acid or sulfate, and thrive in environments near hydrothermal vents at temperatures of 30°C to 113°C (86°F to 235°F). They serve as a key energy source for higher organisms and contribute to sulfur cycling.

Ecosystem Balance: By oxidizing sulfur compounds, these bacteria support the food web's primary consumers, while maintaining equilibrium in sulfur levels, ensuring that energy production remains stable.

Iron-Oxidizing Bacteria:

Iron-oxidizing bacteria oxidize Fe^{2+} into Fe^{3+}, an important process for iron cycling. They are often found near hydrothermal vents at temperatures of 10°C to 60°C (50°F to 140°F), transforming iron minerals into usable forms for other organisms.

Ecosystem Balance: These bacteria are vital for maintaining iron availability in ecosystems, preventing depletion of this essential element and allowing for continued microbial and mineral-based interactions.

2. Secondary Consumers

Microfauna:

These tiny organisms, including protozoa and microscopic worms, feed on chemosynthetic bacteria like methanogens and sulfur-oxidizing bacteria. Microfauna thrive in temperatures ranging from 4°C to 60°C (39°F to 140°F).

Ecosystem Balance: Microfauna bridge the gap between microbial primary producers and larger organisms, ensuring energy transfer through the food web. They help maintain microbial populations by feeding on them, preventing overgrowth and ecosystem imbalance.

Chemolithotrophic Bacteria:

These bacteria derive energy from inorganic compounds and serve as both primary producers and secondary consumers, thriving at temperatures between 4°C and 113°C (39°F to 235°F).

Ecosystem Balance: By consuming inorganic minerals, these bacteria recycle essential elements and sustain the base of the food web, contributing to ecosystem stability.

3. Tertiary Consumers

Giant Tube Worms (Riftia pachyptila):

These large invertebrates depend on symbiotic sulfur-oxidizing bacteria in their trophosome for energy. Found near hydrothermal vents, they thrive at 2°C to 40°C (36°F to 104°F).

Ecosystem Balance: giant tube worms, through their symbiotic relationship with bacteria, support the transfer of energy to higher trophic levels. They stabilize the vent ecosystem by facilitating nutrient cycling and energy flow.

Hydrothermal Vent Clams (Calyptogena magnifica):

Hydrothermal vent clams rely on a symbiotic relationship with sulfur-oxidizing bacteria in their gills. These bacteria oxidize hydrogen sulfide, abundant near hydrothermal vents, to produce energy through chemosynthesis. The clams absorb the nutrients generated by these bacteria, effectively feeding off the energy produced by their symbiotic partners.

So, Calyptogena magnifica clams depend on these bacteria for their nutrition, rather than feeding on other organisms or substances directly.

These large clams rely on sulfur-oxidizing bacteria for nutrition and thrive at temperatures between 5°C and 20°C (41°F to 68°F).

Ecosystem Balance: Clams help regulate bacterial populations and maintain the sulfur cycle, contributing to ecosystem health by forming key trophic links between primary producers and larger predators.

Hydrothermal Vent Crab (Bythograea thermydron):

These crabs are top predators, feeding on smaller invertebrates and organisms. They thrive in extreme conditions near vents, where temperatures range from 2°C to 40°C (36°F to 104°F).

Ecosystem Balance: As apex predators, vent crabs help maintain population control among lower organisms. By regulating species populations, they contribute to the overall stability of the vent ecosystem.

Deep-Sea Vent Fish:

These fish are adapted to the high-pressure, low-light conditions of hydrothermal vent regions and feed on invertebrates and smaller organisms. They survive in temperatures of 2°C to 20°C (36°F to 68°F).

Ecosystem Balance: These fish maintain ecosystem balance by feeding on both invertebrates and secondary consumers, keeping the food web intact and contributing to energy transfer at the top of the ecosystem.

Ecosystem Dynamics:

1. Energy Flow: Energy flows from chemosynthetic bacteria to secondary consumers and eventually to larger predators like crabs and fish. This transfer ensures a steady energy supply throughout the food web.

2. Material Cycling: Sulfur, carbon, and iron cycles are crucial to ecosystem balance. Bacteria facilitate these cycles, maintaining essential nutrients and minerals for other organisms.

3. Symbiotic Relationships: Larger invertebrates like tube worms and clams host symbiotic bacteria, creating stable mutual dependencies that help sustain the food web.

4. Diversity Zones: Hydrothermal vent ecosystems exhibit distinct zones of life, each with specialized species adapted to the unique conditions of their respective environments.

5. Adaptations and Evolution: Organisms in this ecosystem evolve specialized traits, allowing them to thrive under extreme temperature, pressure, and chemical conditions, ensuring long-term ecological stability.

Planets and moon Kepcelis was inspired from:

planet/ moon	Type of planet	mass	radius	Orbital R/AU	star
Enceladus	Ice covered oceanic moon	1.08 × 10^20 kg	252.1 km	238,000 km (from Saturn)	Not applicable (Enceladus orbits Saturn)
Kepler 186-f	Earth-like exoplanet	1.021 × 10^25 kg	7,454 km	0.432 AU	Red dwarf star (Kepler-186, M-type)
Europa	Ice covered oceanic moon	4.80 × 10^22 kg	1,560.8 km	670,900 km (from Jupiter)	Not applicable (Europa orbits Jupiter)
LHS 1140b	Rocky super-Earth	6.98 ×5.972 × 10^24 kg	≈ 9,115 km	0.087 AU	Red dwarf star (LHS 1140, M-type)
TRAPPIST-1e	Earth-like exoplanet	0.69 ×5.972 × 10^24 kg	≈ 5,860 km	0.029 AU	Red dwarf star (TRAPPIST-1, M-type)
ganymede	Ice covered oceanic moon	1.48 × 10^23 kg	≈ 2,634.1 km	1,070,400 km (from Jupiter)	- Ganymede orbits Jupiter

callisto	Ice covered oceanic moon	1.08 × 10^23 kg	≈ 2,410.3 km	1,882,700 km (from Jupiter)	- Callisto orbits Jupiter
Triton	Ice covered moon with cryovolcanism	2.14 × 10^22 kg	≈ 1,353.4 km	354,800 km (from Neptune)	- Triton orbits Neptune
Titan	Ice covered moon with liquid methane/ethane lakes	1.35 × 10^23 kg	≈ 2,574.7 km	1,222,000 km (from Saturn)	- Titan orbits Saturn

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