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ORIGINAL ARTICLE

The potential for photosynthesis in hydrothermal vents: a new avenue for life in the Universe?

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Abstract We perform a quantitative assessment for the potential for photosynthesis in hydrothermal vents in the deep ocean. The photosynthetically active radiation in this case is from geothermal origin: the infrared thermal radiation emitted by hot water, at temperatures ranging from 473 up to 673 K. We find that at these temperatures the photosynthetic potential is rather low in these ecosystems for most known species. However, species which a very high efficiency in the use of light and which could use infrared photons till 1300 nm, could achieve good rates of photosynthesis in hydrothermal vents. These organisms might also thrive in deep hydrothermal vents in other planetary bodies, such as one of the more astrobiologically promising Jupiter satellites: Europa.

Keywords Hydrothermal vent · Thermal radiation · Photosynthesis

1 Introduction

Light energy from the Sun drives photosynthesis to provide the primary source of nearly all of the organic carbon that supports life on Earth (Blankenship 2002). An alternative energy source can be found in hydrothermal vents, such as black smokers located far below the photic zone in the oceans, where unusual microbial and invertebrate populations exist on organic material from CO_2 reduction by chemotrophic bacteria that oxidize inorganic compounds (Van Dover 2000). Hydrothermal vents may resemble the environment in which life evolved (Martin and Russell 2003; Simoncini et al. 2011), and the discovery of geothermal light at otherwise dark deep-sea vents led to the suggestion that such light may have provided a selective advantage for the evolution of photosynthesis from a chemotrophic microbial ancestor that used light-sensing molecules for phototaxis toward nutrients associated with geothermal light (Van Dover et al. 1996; Nisbet et al. 1995).

A bacterium that appears to use light as an auxiliary source of energy to supplement an otherwise chemotrophic metabolism was isolated from the general vicinity of a deep-sea hydrothermal vent (Yurkov et al. 1999; Beatty 2002; Beatty et al. 2005). The discovery of such an organism in this environment would indicate that volcanic or geothermal light is harvested to drive photosynthetic reactions in the absence of light from the Sun. The possibility of geothermal light-driven photosynthesis on Earth relates to speculations about the existence of extraterrestrial life on planets and moons far from the Sun in the Solar System (Chyba and Hand 2001) and, conceivably, in other galaxies.

However, largely due to the high costs of deep sea explorations, hydrothermal vents near submarine volcanoes are far from being thoroughly studied. Thus, in this work we apply a mathematical model of photosynthesis to theoretically assess the photosynthetic potential in deep sea hydrothermal vents.

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