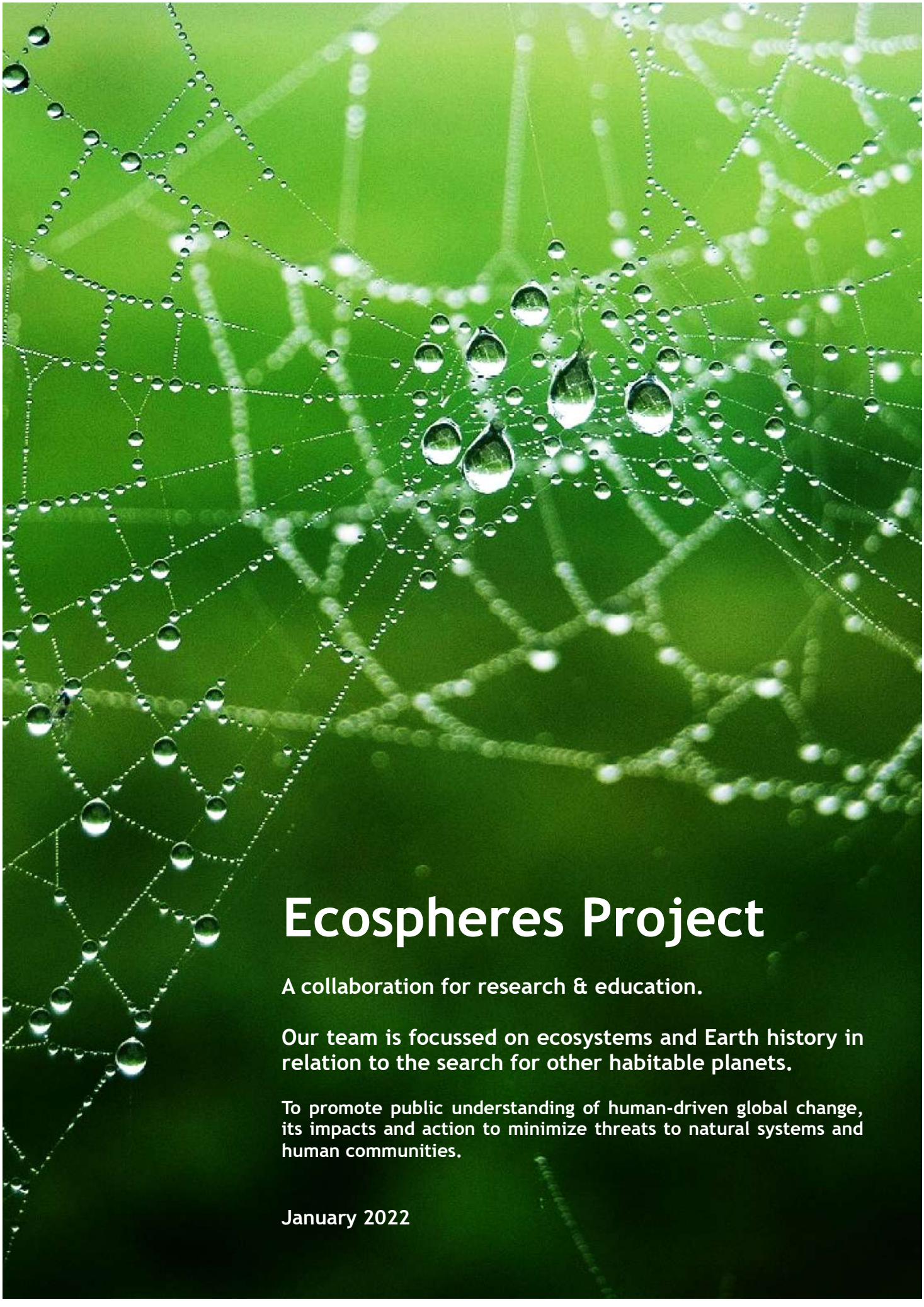


Ecospheres Project

A collaboration for research & education.

Our team is focussed on ecosystems and Earth history in relation to the search for other habitable planets.

To promote public understanding of human-driven global change, its impacts and action to minimize threats to natural systems and human communities.

January 2022

The principal collaborators of the Ecospheres Project are Dr. Martin J. Heath, UK (life & earth sciences) and Dr. Laurance R. Doyle, USA (astrophysics; SETI Institute).

Much of our joint work has been horizon scanning, in which have papers have identified potential areas of future research interests. We have pioneered several rewarding avenues (mostly related to habitable planets) which later developed into major investigations explored by the broader scientific community.

Forested worlds: the next step in the search for life in the universe.

"It could be that the first detection of extra-terrestrial life will be forests".

Statement by Laurance R. Doyle (left) to a congressional hearing at Washington DC, May 9, 2013.

(In centre, Dr. John M. Grunsfeld, veteran astronaut, Associate Administrator, Science Mission Directorate and right, Dr. James Ulvestad, Director, Division of Astronomical Sciences, National Science Foundation).

Forests, the Upsurge and the transformation of Planet Earth.

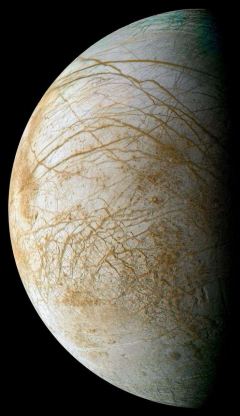
We have emphasised forest ecosystems, which have existed on Earth for about 400 million years. They now cover large areas, sustain huge biomass and biodiversity and likewise play major roles in biogeochemical cycles and in moderating regional climates. Our primate ancestors evolved among the trees, and developed the hand-eye co-ordination that enabled us to carry out ventures such as the construction of the International Space Station. Wood provides structural material and also floats and burns. We have defined also the "Upsurge," a transformation of the Earth System driven by flowering plants (which today comprise ~ 90% of all plants). The Upsurge spans two key events named by other researchers; the "Great Divergence" some 110 million years ago to the current "Great Acceleration" of human impact on the planet. Our civilisation is supported by the fruits in plantations, orchards and fields, and grasses (notably, sugar cane, maize, wheat and rice). If other civilisations have arisen in our Galaxy, we must ask what has served them in the role of flowering plants.

Heath, M. J. (1994). Abstracts and presentation. First International Conference on Circumstellar Habitable Zones. NASA Ames Research Center, Moffet Field, California, U.S.A.. Jan. 19 - Jan. 21. Heath, M. J. (1996). The forest-habitability of Earth-like planets. In L. R. Doyle (Ed.). *Circumstellar Habitable Zones. Proceedings of the First International Conference* pp. 445-457. Menlo Park, CA, USA: Travis House Publications. **Heath, M. J., Dole, L. R. and Stanford P. (2021). Ecospheres: Forests & the Upsurge. Issue 1: June 15, 2021.**

TV projects.

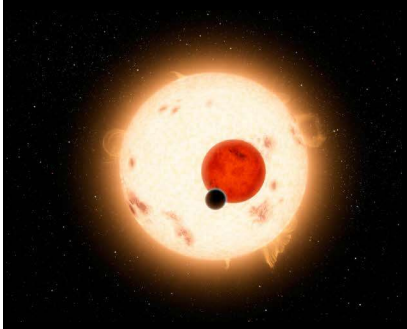
We were consultants and participants on the 2005 two episode Big Wave production *Alien Worlds*, which was based on our published research and we helped to secure funding from National Geographic. *Alien Worlds* won the Royal Television Society (South) award for best factual programme, was the basis of UK Science Museum display, which went on international tour, and was shown in schools to promote interest in science.

Snatching a free gift from an alien ocean.



Jupiter's moon Europa possesses an ocean beneath an icy crust (its thickness is the subject of a major controversy). Our presentation to the Europa Ocean Conference (1996) suggested that if, as is possible in some models, bodies of water can reach the surface, we should expect plumes of water vapour to escape, potentially carrying micro-organisms and their biochemical signatures. These, we argued, might be sampled by a space craft in low orbit. This was an in-principle concept not then supported by new observations or models of plume mechanisms and it was received with scepticism. Recently, however, a couple of teams have claimed potential observations of plumes from Europa and the possibility of plume sampling has been discussed at a 2015 NASA workshop.

Heath, M. J. and Doyle, L. R. (1996). Accessability of Europan Organisms. Presentation to *Europa Ocean Conference, Nov. 12-14, 1996, San Juan Capistrano Research Institute, San Juan Capistrano, California, U.S.A.*.



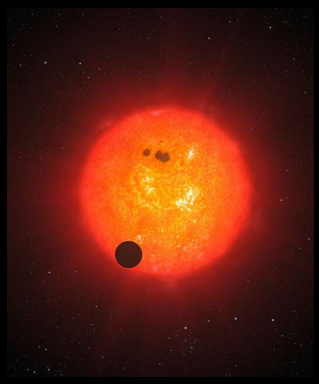
Searching for planets of other suns and flagging up the first object from the Kepler mission that might provide a home for life-as-we-know-it.

Doyle and a colleague **searching ~100,000 light curves of a binary star** (orange and red dwarfs) and he identified its planet as the first to be orbiting around two Suns. Then, as a participating scientist on NASA's Kepler mission, he led the team which, in 2011, confirmed this planet as Kepler-16AB-b. Heath and Doyle announced this as the historic first Kepler object to be of *potential* interest to astrobiologists (previous planets being too hot).

The planet itself was a gas giant. We did not dismiss some authors' suggestions of life in the atmospheres of gas giants, but emphasised that closer analogies to Earth-like biology, might exist on suitable moons, perhaps microbial-grade life, in subsurface habitats.

Doyle, L. R. *et al*. (2011). Kepler-16: A Transiting Circumbinary Planet. *Science* **333**: 1,602-1,606. Heath, M. J. and Doyle, L. R. (2011). Kepler 16: A system of potential interest to astrobiologists. *arxiv.org/pdf/1111.0002*.

Habitable planets of red dwarf stars.

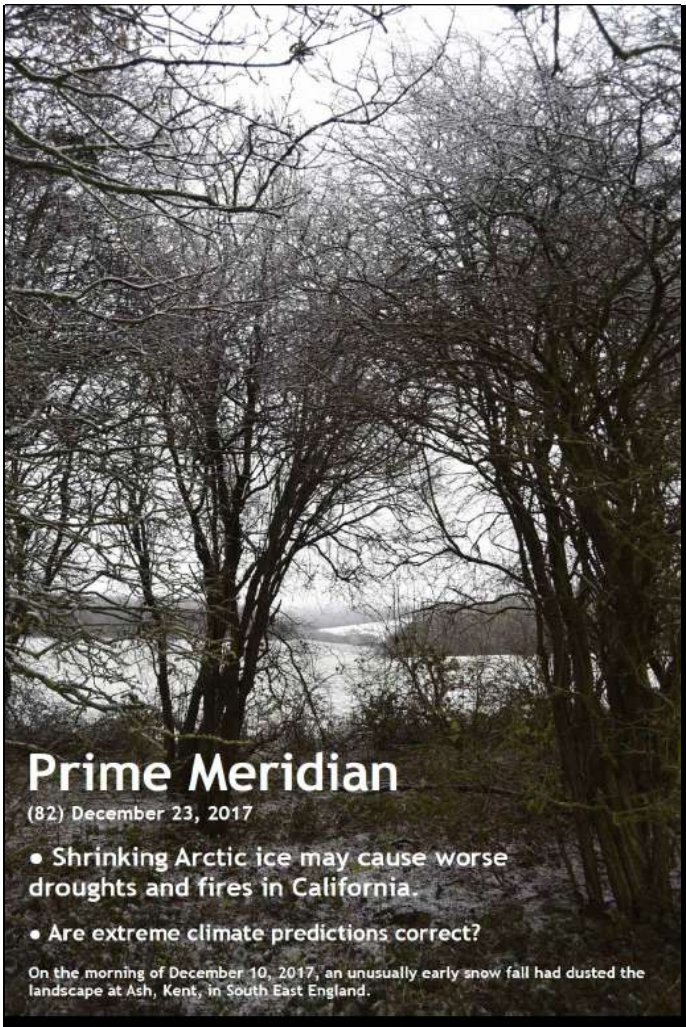


Although they comprise at least 75% of the stars in our Galaxy, red dwarfs had been dismissed as parent suns for habitable worlds. Working with climatologists Manoj Joshi and Bob Haberle, we re-assessed the possibility that planets in tidal lock around red dwarfs might support complex life and concluded that previous work had over-emphasised the dangers of extreme climates, stellar flares and reduced Photosynthetically Active Radiation in red dwarf sunlight. We also looked at the problems associated with planetary environments during the spin-down into synchronous rotation (Heath & Doyle, 2004). A NASA-sponsored workshop was staged by the SETI Institute in 2005 and we participated in the resulting 2007 paper.

Image credit: ESO/L. Calçada http://www.eso.org/public/images/eso0950a/ Heath, M. J., Doyle, L. R., Joshi, M. M. and R. Haberle, R. (1999). Habitability of Planets Around M-Dwarf Stars. *Origins of Life* **29**: 405-424. **Heath, M. J. and Doyle, L. R. (2004). From Near-Synchronously Rotating Planets to Tidal Lock: A New Class of Habitable Planets Examined for Forest Habitability. *Bioastronomy* 2002: Life Among the Stars IAU Symposium R. P. Norris and F. H. Stootman (Eds.) 213: 225-229.** Tarter, J. C *et al*. (2007). A Reappraisal of the Habitability of Planets Around M Dwarf Stars. *Astrobiology* **7**: 30-65.

Today, this is a well-trodden field, with a growing literature and numerous contributors. Other workers have raised serious concerns for the habitability of planets around red dwarf stars, citing potential depletion of atmospheres and oceans as a result of intense stellar activity. Red dwarf stars have masses in the range about half that of our Sun down to 7.5 percent. The fraction of a star involved in convection increases towards lower masses and a star below 35% of a solar mass will be fully convective - and strong convection drives extreme stellar activity.

Our perspective has shifted to a more sceptical standpoint, and we intend, in the course of future work, to re-investigate the opportunities offered by planets of red dwarf stars for Earth-type microbial life and complex life and to explore also the kinds of biological adaptations that might aid survival in a range of non-Earth-like environments.



Summer has enjoyed hot days and warm nights with brilliant planets gleaming in the sky. On the day after the summer solstice, and beneath a bright blue sky, pyramidal orchids are flourishing in Northfield (near New Ash Green, Kent) June 23, 2018.

Prime Meridian (90) June 30, 2018

What does climate change mean, not only for our civilisation, but also for the fate of other civilisations elsewhere in our Galaxy?

We investigate a recent and thought-provoking claim published this month by scientists in the USA and Germany. We also look back on our own research and lectures, exploring implications for climate change for the Earth and other planets.

Action for planetary stewardship.

Our first and most urgent task is to participate in the take decisive action against the growing global ecological crisis.

Prime Meridian newsletter discusses developments in global environmental issues and follows the cycle of the seasons in South East England. This region includes the historic Prime Meridian at Greenwich, on the hill above the River Thames. Our newsletter steps back at the same time to look at the Earth in its astronomical context and it pursues the search for other habitable worlds.

Our technology civilisation has provided our species with widespread benefits, but posses immmense threats to both nature and human communities. It is essential, we argue, to look beyond the very real Climate Crisis and think in terms of a complex Earth Crisis.

"*Planetary stewardship*" has been a much-used cliché. We emphasise, however, that in the same way that a desire to help injured people doesn't amount to a medical degree, so to our civilisation will not graduate to true planetary stewardship unless nations around the world support vigorous research. We don't need further scientific research to demonstrate that the devastating impact caused by human activity is real, but it will be necessary for extensive and continuing research to help us better understand how we can stop destroying Earth's ecosphere and to enable us to find the best ways to protect human communities. Science must be the key to planetary stewardship. It would be a profound irony were astrobiologists to find another habitable planet, while we are in the throes of harming our own habitable world.

We pursue an integrated perspective of challenges and opportunities of the 21st Century. Topics include the Anthropocene (the geological time dominated by humans), the Great Acceleration (of human activity and impact on Planet Earth), planetary boundaries (environmental limits to safe operation for humans), tipping points (which might cause irreversible damaging), geoengineering (with the potential to back-fire) and the Technological Singularity (at which human intelligence may no lomger be able to predict or keep up with ever faster developments, driven by AI). We seek to be vanguards of environmentalism on the high fronter. We urge that as space probes explore other worlds for evidence of life, *Homo sapiens* must not extend its ecological damage beyond the Earth.

Heath, M. (1989). Earth a problem in planetary management. *Journal of the British Interplanetary Society* 42: 559-566. Heath, M. J. (1990a). Paper presented to conference *Life and Death of the Earth*. Greenwich Community College, London, U.K.. March 31, 1990. Heath, M. J. (1990b). Life and Death of the Earth. *Astronomy Now* 4: 20-21.

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