Black hole sun could support bizarre life on orbiting planets

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According to the second law of thermodynamics, life requires a temperature difference to provide a source of useable energy. Life on Earth exploits the difference between the sun and the cold vacuum of space, but what if you flip the temperatures around, with a cold sun and a hot sky?

That's exactly what a planet orbiting a black hole would see, says Tomáš Opatrný of Palacký University in Olomouc, Czech Republic – though it wouldn't look much like the one imagined by the grunge band Soundgarden.

Bright but cold

Despite the name, most black holes are among the brightest objects in the universe, because gas and other matter falling in is superheated and glows as it accretes. But a satiated black hole effectively has zero temperature, barring a trickle of particles released by a process called Hawking radiation, meaning it could potentially act as a cold sun, says Opatrný. "We need a fairly old black hole that has already cleared its surroundings and which is not further fed."

Compared to this chilly character, the rest of the universe is a relatively balmy 2.7 kelvin (about -270 ?C), thanks to the cosmic microwave background (CMB), the heat left over from the explosion of the big bang. The team calculated that an Earth-sized planet orbiting a black hole that appeared a similar size to our sun in the sky could extract around 900 watts of useful power from this temperature difference – enough for life to potentially exist, but hardly enough to run a civilisation.

Complex life

But the CMB was hotter earlier on in the universe – Avi Loeb of Harvard University has previously pointed out the universe's background temperature would be 300 kelvin (27 ?C) around 15 million years after the big bang, making it warm enough to host liquid water. At this temperature, a planet around a sufficiently cool black hole would receive 130 gigawatts of power, around a millionth of what the sun provides Earth. That's enough to support complex life, though so short into the universe's existence, it's unlikely that it would have had time to evolve enough to explore this power source.

Wondering if any more power might be available, the team turned to the film *Interstellar*, in which a world called Miller's planet orbits very close to a massive, spinning black hole called Gargantua. General relativity means the black hole's gravitational pull slows time on the planet so that 1 hour is equal to seven years off-world, a factor of around 60,000.

"We saw the movie, it was a very interesting idea, but then we started thinking about the problems," says Opatrný.

Aluminium tsunamis

The energy of light is proportional to its frequency. This means that when light from the CMB hits Miller's planet, and its frequency is increased by this time dilation, its energy increases. With a time-dilation factor of around 60,000, Miller's planet would be heated to nearly 900 ?C.

In the film, the planet is swept by huge tidal waves of water, but Opatrný says his calculations mean molten aluminium would be more likely. Conditions would be cooler if the planet were slightly further out from the black hole, lessening the effects of time dilation and making it more hospitable to life. "It's interesting that [the analysis] suggests the microwave background would be disastrous for observers on the planet, making the movie once again less realistic," says Lawrence Krauss of Arizona State University.

Loeb thinks that the theoretical idea of a cold sun and a hot sky to support life is interesting, but in practice it is unlikely to occur in the universe. "There is always matter falling at some level into a black hole," he says, meaning the black hole sun wouldn't stay cold enough for long.

Our future home

Life will eventually have to emigrate to planets around black holes once all the stars die out, but that won't be for around 100 trillion years. Even then, it's more likely that any future beings will absorb light from accreting matter rather than dwell under a cold sun, as by then the CMB will have faded into nothing. "When the stars are gone, black holes will be a last-resort source of energy," says Krauss. "For the practical future, there are.