What happens if you put a black hole into the sun?

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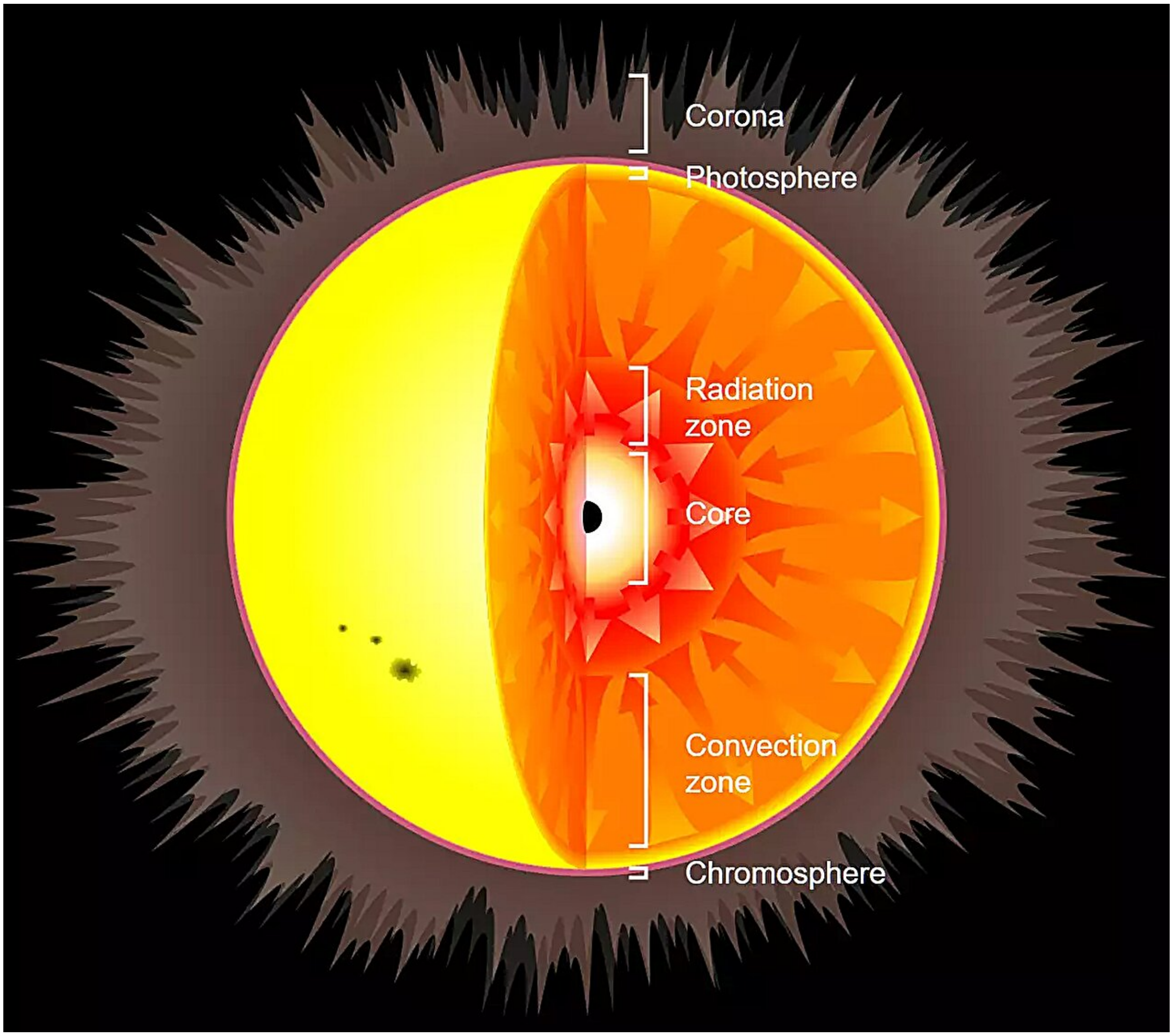


Artist's impression of putting a small black hole at the center of the sun in a thought experiment. Credit: Wikimedia/Creative Commons.

In a hypothetical scenario, small, primordial black holes could be captured by newly forming stars. An international team, led by researchers at the Max Planck Institute for Astrophysics, has now modeled the evolution of these so-called "Hawking stars" and found that they can have surprisingly long lifetimes, resembling normal stars in many aspects. The work is published in *The Astrophysical Journal*.

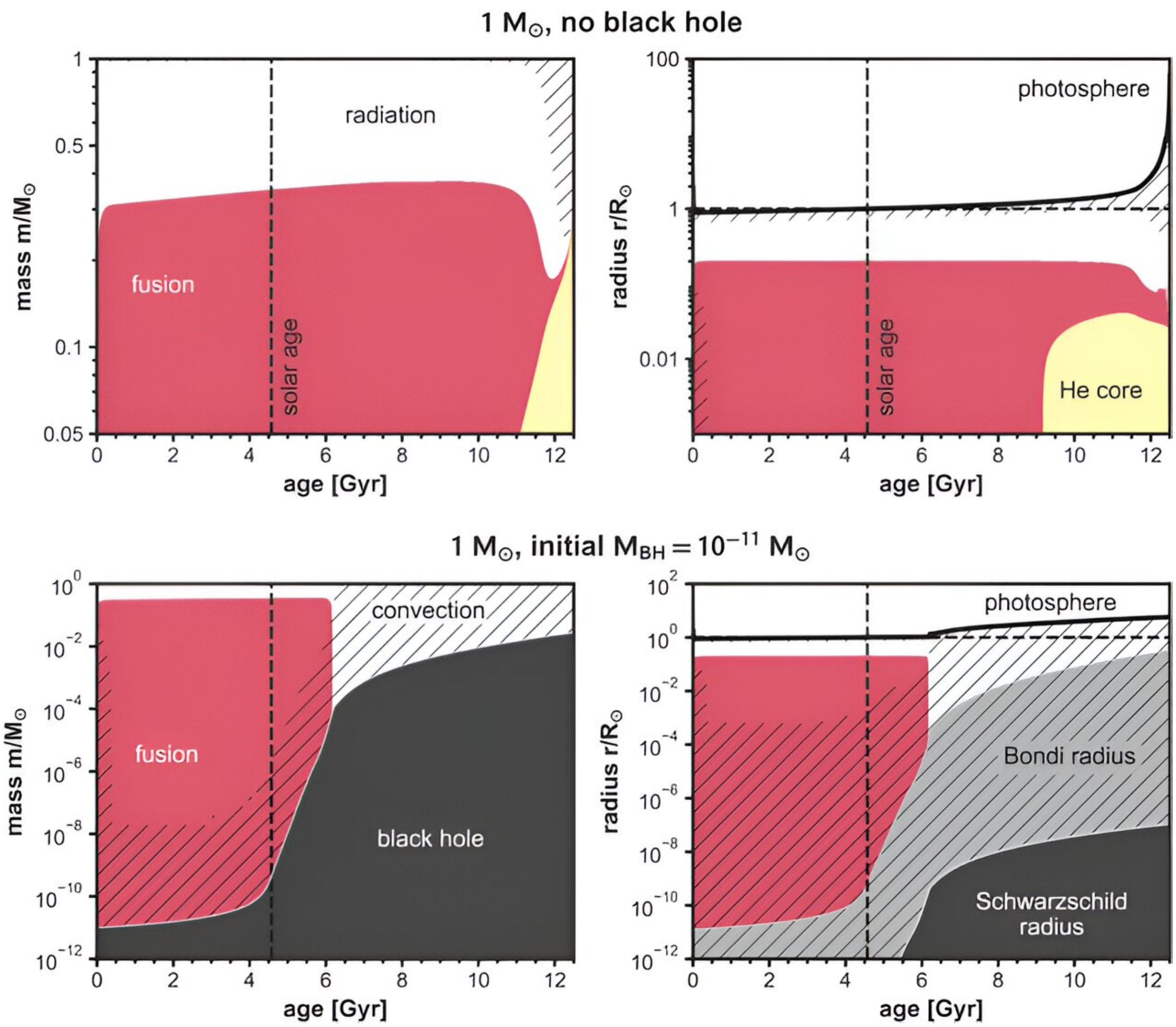
Asteroseismology could help to identify such stars, which in turn could test the existence of primordial black holes and their role as a component for dark matter.

Let's do a scientific exercise: If we assume that a large number of very small black holes where created just after the Big Bang (so-called primordial black holes), some of them might be captured during the formation of new stars. How would this affect the star during its lifetime?

"Scientist sometimes ask crazy questions in order to learn more," says Selma de Mink, director of the stellar department at the Max Planck Institute for Astrophysics (MPA). "We don't even know whether such primordial black holes exist, but we can still do an interesting thought experiment."

Primordial black holes would have formed in the very early universe with a wide range of masses, from some as small as an asteroid up to thousands of solar masses. They could constitute an important component of dark matter, as well as being the seeds for the supermassive black holes at the center of present-day galaxies.

With a very small probability, a newly forming star could capture a black hole with the mass of an asteroid or a small moon, which would then occupy the star's center. Such a star is called a "Hawking star," named after Stephen Hawking, who first proposed this idea in a paper in the 1970s.



Kippenhahn diagrams showing the evolution of the interior of the Sun with and without a central BH. The left panels show the mass distribution, with regions of energy generation and transport indicated. The right panels show the radial distribution, with the radius of the photosphere (black line) and the solar radius (horizontal dashed line) indicated. The top panels correspond to a normal solar evolution model evolved through the MS until core hydrogen exhaustion and up through hydrogen shell burning as a red giant. The bottom panels show a model that is consistent with the present Sun with a BH growing at its center. Nuclear fusion (red) provides the bulk of the solar luminosity until the BH is of sufficient mass to quench the reactions. The BH drives convection (hatches), which mixes the innermost parts of the core, and eventually the entire star. Note the differences in the y-axis scale between the panels. Credit: *The Astrophysical Journal* (2023). DOI: 10.3847/1538-4357/ad04de

The black hole at the center of such a Hawking star would grow only slowly, as the infall of gas to feed the black hole is hampered by the outflowing luminosity. An international team of scientists has now modeled the evolution of such a star with various initial masses for the black hole and with different accretions models for the stellar center. Their astonishing result: when the black hole mass is small, the star is essentially indistinguishable from a normal star.

"Stars harboring a black hole at their center can live surprisingly long," says Earl Patrick Bellinger, MPA Postdoc and now Assistant Professor at Yale University, who led the study. "Our sun could even have a black hole as massive at the planet Mercury at its center without us noticing."

The main difference between such a Hawking star and a normal star would be near the core, which would become convective due to the accretion onto the black hole. It would not alter the properties of the star at its surface and would elude present detection capabilities. However, it could be detectable using the relatively new field of asteroseismology, where astronomers are using acoustic oscillations to probe the interior of a star.

Also in their later evolution, in the red giant phase, the black hole might lead to characteristic signatures. With upcoming projects such as PLATO, such objects might be discovered. However, further simulations are needed to determine the implications of putting a black hole into stars of various masses and metallicities.

If primordial black holes were indeed formed soon after the Big Bang, looking for Hawking stars could be one way to find them.

"Even though the sun is used an exercise, there are good reasons to think that Hawking stars would be common in globular clusters and ultra-faint dwarf galaxies," points out Professor Matt Caplan at Illinois State University, co-author of the study.

"This means that Hawking stars could be a tool for testing both the existence of primordial black holes, and their possible role as dark matter."

More information: Earl P. Bellinger et al, Solar Evolution Models with a Central Black Hole, *The Astrophysical Journal* (2023). DOI: 10.3847/1538-4357/ad04de

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