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[Nailing Down Goldilocks: What's "Just Right" for Exo-Earths?](#)

Written by [Jean Tate](#)

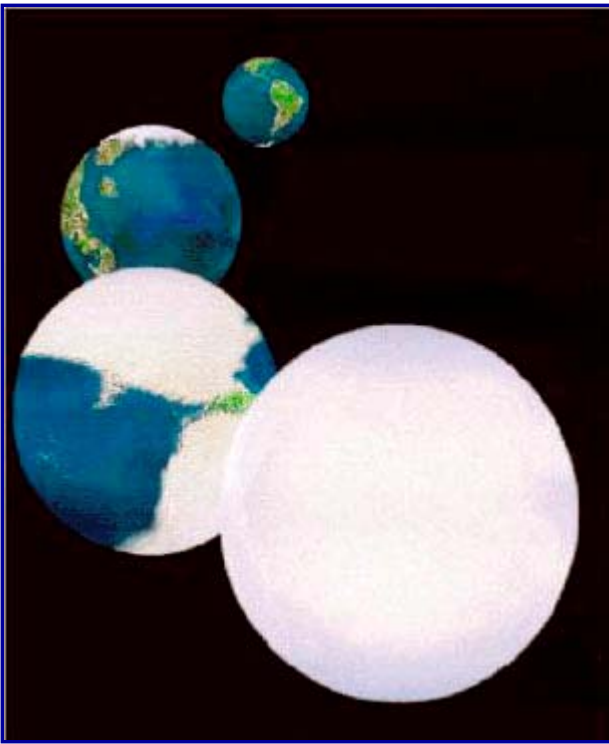


For Goldilocks, the porridge had to be not too hot, and not too cold ... the right temperature was all she needed.

For an [Earth-like planet](#) to harbor life, or multicellular life, certainly temperature is important, but what else is important? And what makes the temperature of an exo-Earth "just right"?

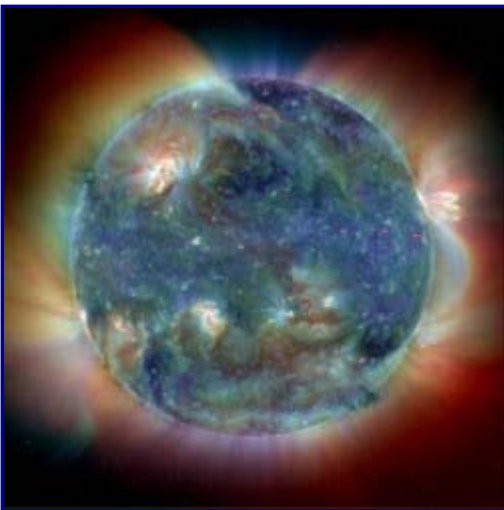
Some recent studies have concluded that answering these questions can be surprisingly difficult, and that some of the answers are surprisingly curious.

Consider the tilt of an exo-[Earth's axis](#), its obliquity.



In the "Rare Earth" hypothesis, this is a Goldilocks criterion; unless the tilt is kept stable (by a [moon](#) like [our Moon](#)), and at a "just right" angle, the climates will swing too wildly for multicellular life to form: too many snowball Earths (the whole globe covered in snow and ice), or too much risk of a runaway greenhouse.

"We find that [planets](#) with small ocean fractions or polar continents can experience very severe seasonal climatic variations," Columbia University's David Spiegel writes*, summing up the results of an extensive series of models investigating the effects of obliquity, land/ocean coverage, and rotation on Earth-like planets, "but that these planets also might maintain seasonally and regionally habitable conditions over a larger range of orbital radii than more Earth-like planets." And the real surprise? "Our results provide indications that the modeled climates are somewhat less prone to dynamical snowball transitions at high obliquity." In other words, an exo-Earth tilted nearly right over (much like [Uranus](#)) may be less likely to suffer snowball Earth events than our, Goldilocks, Earth!



Ultraviolet view of the Sun. Image credit: SOHO

Consider ultra-violet radiation.

"[Ultraviolet](#) radiation is a double-edged sword to life. If it is too strong, the terrestrial biological systems will be damaged. And if it is too weak, the synthesis of many biochemical compounds cannot go along," says Jianpo Guo of China's Yunnan Observatory** "For the host [stars](#) with effective temperatures lower than 4,600 K, the ultraviolet habitable zones are closer than the habitable zones. For the host stars with effective temperatures higher than 7,137 K, the ultraviolet habitable zones are farther than the habitable zones." This result doesn't change what we already knew about habitability zones around [main sequence stars](#), but it effectively rules out the possibility of [life on planets](#) around post-red [giant stars](#) (assuming any could survive their homesun going [red giant](#)!)



(Credit: NASA)

Consider the effects of clouds.

Calculations of the habitability zones – the radii of the [orbits](#) of an exo-Earth, around its homesun – for main sequence stars usually assume an astronomers' heaven – permanent clear skies (i.e. no clouds). But Earth has clouds, and clouds most definitely have an effect on average global temperatures! "The [albedo](#) effect is only weakly dependent on the incident stellar spectra because the optical properties (especially the scattering albedo) remain almost constant in the wavelength range of the maximum of the incident stellar radiation," a German team's recent study*** on the effects of clouds on habitability concludes (they looked at main sequence homesuns of spectral classes F, G, K, and M). This sounds like Gaia is Goldilocks' friend; however, "The [greenhouse effect](#) of the high-level cloud on the other hand depends on the temperatures of the lower atmosphere, which in turn are an indirect consequence of the different types of central stars," the team concludes (remember that an exo-Earth's global temperature depends upon both the albedo and greenhouse effects). So, the take-home message? "Planets with Earth-like clouds in their atmospheres can be located closer to the central [star](#) or farther away compared to planets with clear sky atmospheres. The change in distance depends on the type of cloud. In general, low-level clouds result in a decrease of distance because of their [albedo effect](#), while the high-level clouds lead to an increase in distance."

"Just right" is tricky to pin down.

* lead author; Princeton University's Kristen Manou and Columbia University's Caleb Scharf are the co-authors ("Habitable Climates: The Influence of Obliquity", *The Astrophysical Journal*, Volume 691, Issue 1, pp. 596-610 (2009); [arXiv:0807.4180](#) is the preprint)

** lead author; Fenghui Zhang, Xianfei Zhang, and Zhanwen Han, all also at the Yunnan Observatory, are the co-authors ("Habitable zones and UV habitable zones around host stars", [Astrophysics and Space Science, Volume 325, Number 1, pp. 25-30 \(2010\)](#))

*** "Clouds in the atmospheres of extrasolar planets. I. Climatic effects of multi-layered clouds for Earth-like planets and implications for habitable zones", Kitzmann et al., accepted for publication in [Astronomy & Astrophysics](#) (2010); [arXiv:1002.2927](#) is the preprint.

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