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The future of life on Earth: dynamical evolution of the Solar System after a sub-100 au stellar flyby

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Given the inexorable increase in the Sun's luminosity, Earth will exit the habitable zone in ~ 1 billion years. There is a negligible chance that Earth's orbit will be perturbed during that time by internal Solar System dynamics. However, there is a ~ 1% chance per billion years that a star will pass within 100 au of the Sun. Here, we use N-body simulations to evaluate the possible evolutionary pathways of the planets under the perturbation from a close stellar passage. We find a ~ 92% chance that all eight planets will survive on orbits similar to their current ones if a star passes within 100 au of the Sun. Yet a passing star may disrupt the Solar System, by directly perturbing the planets' orbits or by triggering a dynamical instability. Mercury is the most fragile, with a destruction rate (usually by collision with the Sun) higher than that of the four giant planets combined. The most probable destructive pathways for Earth are to undergo a giant impact (with the Moon or Venus) or to collide with the Sun. Each planet may find itself on a very different orbit than its present-day one, in some cases with high eccentricities or inclinations. There is a chance that Earth could end up on a more distant (colder) orbit, through re-shuffling of the system's orbital architecture, ejection into interstellar space (or into the Oort cloud), or capture by the passing star. We quantify plausible outcomes for the post-flyby Solar System.