Back in 2004 Bromley & Kenyon simulated two young stars whizzing by each other and found our Sun might grab a stray planet during a close flyby . In fact, they suggested that Sedna – a distant icy world – could be such a “captured” planet. It’s a tiny chance (a few percent), but it shows gravity can in principle transfer a planet between stars. More recently, mathematician Edward Belbruno showed that the combined gravity of the Sun and the Milky Way can permanently trap an interstellar object into solar orbit. In other words, if a rogue planet blasted through our system just right, galactic forces could lock it into orbit. So yes, physics says it’s possible in principle for a star to gain a planet – it just requires super-rare conditions or cosmic luck

But in practice adding a planet is extremely chaotic. Gravitational dynamics aren’t linear – it’s the dreaded many-body problem.Obviously, if two bodies orbit a star and their paths come too close, “the more likely they are to... collide, or for one to be ejected from the system.” With three or more bodies you can’t solve it with a simple formula; you have to simulate and see what happens . In other words, small changes can snowball into disaster.

I mean, detailed simulations show an extra world in our system is usually catastrophic, heres an interesting one, UC Riverside astrophysicist Stephen Kane ran thousands of models inserting a “**super-Earth**” (a few times Earth’s mass) between Mars and Jupiter. Nearly every outcome was disastrous for the inner planets. In many runs, Mercury, Venus and even Earth got kicked out of orbit. Space.com summarized Kane’s results: “All four inner planets — Mercury, Venus, Mars and Earth — are particularly vulnerable; some or all four got kicked out of the solar system in many cases” . The simulations never forced Jupiter or Saturn out, but sometimes Jupiter did fling the new planet (and even Uranus) back out to restore balance . Kane himself noted that “depending on the mass and exact location of a super- Earth, its presence could ultimately eject Mercury and Venus as well as Earth” . He found that only an extremely fine-tuned planet (very light and placed exactly between Mars and Jupiter) could stay for long – and even then “small moves in any direction... things would go poorly, Our Solar System is like intricate clock gears – add more gears and it all breaks” thats a pretty cool statement Kane

We even looked at exotic configurations like co-orbital planets (two planets sharing nearly the same orbit). A 2023 N-body study by Raymond et al. tested adding extra Earths at Earth’s orbit (and twins at Venus/Mars orbits) to see if “trojan” planets could last. They found some crazy setups survived for a billion years (for example, three Earth-mass bodies and three Venus-mass bodies in horseshoe orbits remained stable) 9 – but none worked if you tried to give all four inner planets co-orbiting siblings. In their words, “no simulations were stable with co-orbitals of all four terrestrial planets at once” 9 . Basically, co-orbital tricks also demand extreme tuning. If you tried to drop a nice new Earth at a Lagrange point or swap places, it won’t easily stay put unless everything else lines up just right.

On top of that, classic analyses of planetary spacing show there’s almost no room left for extra worlds. Stephen Dole’s 1964 study (in Habitable Planets for Man) calculated “forbidden zones” around each planet – regions where no other body can have a stable orbit. Dole found that

about half the inner Solar System lies in these forbidden zones, meaning you can't just slip another Earth-size planet into the gaps

In fact, he concluded only maybe twice as many Earth-like planets could fit in our solar system. That matches what simulations see: perhaps you could wedge a tiny new world far from the giants (like at the very edge of the system) or in the asteroid belt at a special resonance, but not in the crowded inner system. Everywhere else, the gravitational "forbidden zones" and the perturbations of Jupiter/ Saturn will slam the door shut on long-term stability.

Putting it all together: so far, every serious study says it's essentially impossible to casually insert a new planet into our Solar System without chaos. Tens of thousands of simulation-years have shown even a modest extra planet causes planets to collide or fly away.

That said, the idea isn't completely forbidden by physics – it's just fantastically hard. We've seen that gravity itself could capture planets (as with Sedna or rogue planetoids), and exoplanet systems show all sorts of arrangements. In a distant future with super-advanced tech (or the right cosmic circumstances) one could imagine maneuvering a mini-planet or capturing an interstellar one.

Heres some hints since you read through my yapping :D
Even though nearly every simulation screams "instability!" when you drop a planet into our so called perfectly knit Solar System, nature does offer a few cozy nooks!
– Trojan swarms: Jupiter, Neptune, and maybe even Mars - harbor stable Lagrange points where bodies can co-orbit for billions of years.
– Kuiper Belt & Oort Cloud: Vast, distant reservoirs where rogue worlds (like the hypothesised Planet Nine) could hide without wrecking the inner planets.
– Captured interstellar objects: We know Sedna orbits oddly, and studies show galactic tides or stellar flybys can temporarily, or even permanently, trap wandering planets.

So yes, inserting a new Earth-mass world at 1 AU is basically, ahem, asking for disaster, but slinging one out beyond 30 AU, tucking it into a Trojan L4/L5 pocket, or capturing it via a precise cosmic encounter? Those are real, scientifically plausible scenarios.

That's exactly why this simulation project still matters: we're exploring the fringes of gravitational stability, testing the outer boundaries and Trojan hideaways, asking "what if?" in places where the Solar System might still have room to surprise us. In the spirit of genuine research, every run of our code becomes an experiment in cosmic possibility, and every rare stable configuration we find is a tiny victory for Doofen- I mean humanity – against the odds.

Keep that hope alive, the universe is vast, and maybe you could make "impossible" solar systems spring to life in the dark corners of space

Here, for all of you asking, “um, source?” :

Did Our Sun Capture Alien Worlds? – UNews Archive
https://archive.unews.utah.edu/news_releases/did-our-sun-capture-alien-worlds/

Study Finds Rogue Planets Can Become Permanently Trapped in Sun’s Orbit - Astrobiology
https://astrobiology.com/2024/06/study-finds-rogue-planets-can-become-permanently-trapped-in-suns-orbit.html

Gravity - How close to themselves could be two planets orbits?
https://worldbuilding.stackexchange.com/questions/224551/how-close-to-themselves-could-be-two-planets-orbits

Here's the impact a super-Earth would have on our solar system | Space
https://www.space.com/super-earth-impact-solar-system-study

The planet that could end life on Earth | UCR News | UC Riverside
https://news.ucr.edu/articles/2023/03/07/planet-could-end-life-earth

[2304.09209] Constellations of co-orbital planets: horseshoe dynamics, long-term stability, transit timing variations, and potential as SETI beacons
https://ar5iv.labs.arxiv.org/html/2304.09209

Observational constraints on the orbit and location of Planet Nine in the outer solar system and similar papers:

https://arxiv.org/abs/1603.05712

https://arxiv.org/abs/1902.10103

https://arxiv.org/abs/1604.07424

Real planet nine speculations:

https://science.nasa.gov/universe/exoplanets/planet-nine/

https://www.konstantinbatygin.com/planet-nine-and-the-distant-solar-system?

https://www.caltech.edu/about/news/caltech-researchers-find-evidence-real-ninth-planet-49523?

Code resources:

Machine-learning approach for mapping stable orbits around planets | Astronomy & Astrophysics (A&A)
https://www.aanda.org/articles/aa/full_html/2025/01/aa51831-24/aa51831-24.html

REBOUND https://rebound.readthedocs.io/en/latest/