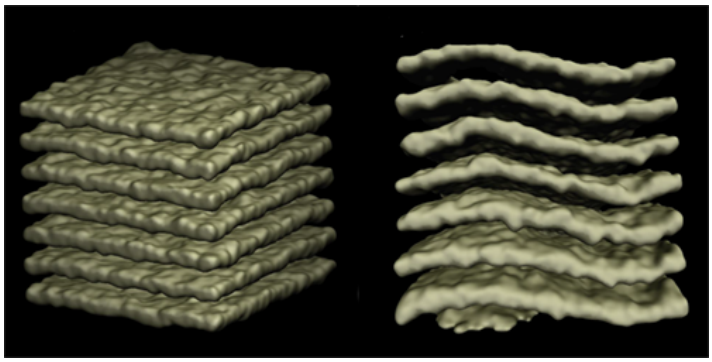
Hot "Pasta" Beneath a Star's Crust

Simulations find that pasta phases beneath a neutron star's crust could dominate the star's neutrino emission.

By **Jessica Thomas**

Beneath the crust of a neutron star lies nuclear matter that's a trillion times denser than water. At this density, models predict that the star's nucleons—mostly neutrons but also protons—practically touch, forming dense spaghetti-like strands or lasagna-like layers within less-dense voids. Zidu Lin of Arizona State University and colleagues now predict the influence of these aptly named pasta phases on the neutrino emission from the star [**1**]. Since this emission is a big part of a neutron star's heat loss, the calculations could influence the understanding of how the stars evolve.

Neutron stars produce neutrinos through the beta decay of neutrons and protons. This emission, and the heat it carries away, is thought to be strongest at a star's core, where the matter in the star is at its densest, and a single nucleon can trigger a decay. In the less dense crust, by contrast, two particles are needed to drive the decay, and neutrino emission is weaker. But a **2004 paper** suggested that pasta phases—because of their nonuniformity—could also drive the single-particle process. If that's true, some low-mass neutron stars would release more heat from their crust than from their core.



Credit: Z. Lin *et al.* [**1**]

Using molecular dynamics calculations, Lin and co-workers explored this possibility for a wide "menu" of pasta phases, including gnocchi, waffle, lasagna, and antispaghetti—a tangle of thread-like voids. When they assumed a low electron fraction in the crust (3%), the crust out-emitted the core by up to a factor of 2000 (for gnocchi). At a slightly higher electron fraction (5%), this factor rose to more than 60,000 (for lasagna). Knowing that pasta phases could enhance the cooling of a star might, the researchers say, influence the interpretation of future observations.

Jessica Thomas is the Editor of *Physics*.

REFERENCES

1. Z. Lin *et al.*, "Fast neutrino cooling of nuclear pasta in neutron stars: Molecular dynamics simulations," **Phys. Rev. C 102, 045801 (2020).**