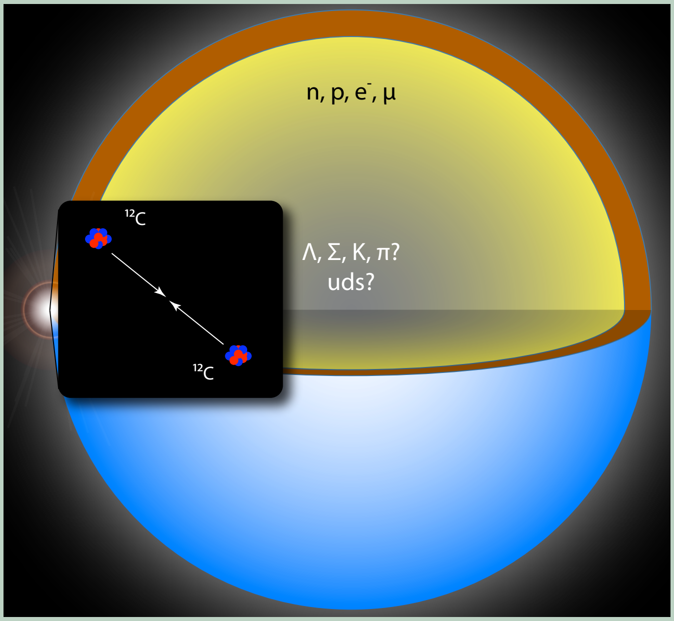
The Joint Institute for Nuclear Astrophysics

JINA

"Faster reacting" $^{12}C + ^{12}C$: Implications for neutron star superbursts



Cutaway schematic of a neutron star. While the core (yellow) contains nucleons and possibly more exotic particles, the crust (brown) contains "normal" nuclei such as ^{12}C. If the crust is heated sufficiently via accretion, the ^{12}C nuclei can "fuse" (inset) and produce a powerful explosion. The properties of the explosion provide information about the physics of the deep crust and core.

Image credit: E. Brown (JINA/ MSU)

Superbursts are powerful explosions observed from accreting neutron stars. The leading explanation for these superbursts is that they are triggered by thermally unstable fusion of ^{12}C nuclei. Observationally inferred superburst ignition depths are shallower, however, than models predict. A possible resolution to this mystery has been proposed by JINA visitor R. Cooper and JINA members A. Steiner and E. Brown. Cooper et al. first showed that other reactions, such as electron captures or reactions with lighter nuclei such as ^{4}He are infeasible. Cooper et al. then examined the $^{12}C + ^{12}C$ fusion rate. The reaction cross section (a measure of the likelihood that two colliding ^{12}C nuclei will fuse) is experimentally unknown at astrophysically relevant energies, but resonances (strong enhancements in the cross-section at certain specific energies) exist in the $^{12}C + ^{12}C$ system throughout the entire measured energy range. Thus it is likely, and in fact has been predicted, that a resonance exists near an energy relevant for ^{12}C nuclei in the dense crust of an accreting neutron star. Cooper et al. showed that such a hypothetical resonance would decrease the theoretically predicted superburst ignition depth by up to a factor of 4; in this case, observationally inferred superburst ignition depths would accord with model predictions for a range of plausible neutron star parameters. Determining whether such a strong resonance in fact exists may be possible with proposed underground accelerators, such as at DUSEL. If such a resonance exists, it would also lower the temperature at which ^{12}C ignites in massive post-main-sequence stars. This in turn might have consequences for nucleosynthesis.

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