r-mode instability windows for superfluid neutron stars

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The finite-temperature r-mode spectrum of a slowly rotating superfluid Newtonian neutron star is calculated neglecting the entrainment between neutron and proton liquid components (i.e., neglecting the off-diagonal element of the entrainment matrix). It is shown that for 'minimal' NS core composition (neutrons, protons, and electrons) only two $m = 2$ r-modes exist — normal mode, which is similar to ordinary r-mode in a nonsuperfluid star, and a superfluid temperature-dependent mode. Accounting for muons in the core dramatically modifies the oscillation spectrum, resulting in an infinite set of superfluid r-modes, whose frequencies vary with temperature. It is demonstrated that the normal r-mode can exhibit avoided crossings with superfluid modes at certain "resonance" temperatures, where it dissipates strongly, which leads to substantial suppression of the r-mode instability near these temperatures. The corresponding instability windows are calculated and discussed.

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