Radiation from neutron stars with internal variable heaters

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We extend our studies [1] of thermal radiation from neutron stars with internal heaters in the crust by considering variable heaters. We have simulated [2] variations of the thermal surface luminosity of the star $L_s(t)$ produced by the heater whose power $L_h(t)$ is varied over a certain period of time Δt. We model either internal outbursts or heat drops (increasing or decreasing $L_h(t)$) and study the conditions at which the variability of the heater produces noticeable variability of $L_s(t)$ that can be used to explore physical conditions in the heater's region. We consider neutron stars with standard neutrino cooling from the core (via modified Urca process) and with the neutrino cooling enhanced by the direct Urca process. We examine different positions and powers of the heating layer in the crust, different heat variation times Δt including effects of superfluidity of free neutrons in the crust.

It was found that only a small fraction of heat is emitted by photons through the surface, whereas the rest of the heat energy is emitted by neutrinos. To increase the surface emission it is profitable to shift the heater closer to the surface. Time variations of $L_s(t)$ are distorted with respect to the variations of $L_h(t)$. For instance, in the case of an internal outburst, the variation of $L_s(t)$ is delayed and broadened relative to $L_h(t)$. If the shape of $L_h(t)$ is symmetrical with respect to the internal outburst peak maximum t_0, the shape of the surface luminosity can be strongly asymmetrical and contain an extended tail. The presence of crustal superfluidity can strongly reduce the time dilatation and broadening of $L_s(t)$ and considerably enhance an amplitude of $L_s(t)$ for relatively deep heater's location. In the case of very strong heaters and/or warm stars, variations of $L_s(t)$ are greatly reduced because the generated heat is efficiently carried away by neutrinos just from the heater. All in all, neutron stars tend to hide their internal activity.

Applications of the results to study the internal activity of neutron stars in soft X-ray transients, magnetars and other neutron stars are discussed.

References

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