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# A neutron star stiff equation of state derived from cooling phases of the X-ray burster 4U 1724-307

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## Abstract

Thermal emission during X-ray bursts is a powerful tool for determining neutron star (NS) masses and radii if the Eddington flux and the apparent radius in the cooling tail can be measured accurately and distances to the sources are known. We propose here an improved method of determining the basic stellar parameters using the data from the cooling phase of photospheric radius expansion (PRE) bursts covering a large range of luminosities. Because at that phase the blackbody apparent radius depends only on the spectral hardening factor (color correction), we suggest fitting the theoretical dependences of the color correction versus flux in Eddington units to the observed variations of the inverse square root of the apparent blackbody radius with the flux. For that we use a large set of atmosphere models for burst luminosities varying by three orders of magnitude and for various chemical compositions and surface gravities. We show that spectral variations observed during a long PRE burst from 4U1724-307 are entirely consistent with the theoretical expectations for the passively cooling NS atmospheres. Our method allows us to more reliably determine both the Eddington flux (which is found to be smaller than the touchdown flux by 15%) and the ratio of the stellar apparent radius to the distance. We then find a lower limit on the NS radius of 14km for masses below 2.3M ⊙, independently of the chemical composition. These results suggest that the matter inside NSs is characterized by a stiff equation of state. We also find evidence in favor of hydrogen-rich accreting matter and obtain an upper limit to the distance of 7kpc. We finally show that the apparent blackbody emitting area in the cooling tails of the short bursts from 4U1724-307 is two times smaller than that for the long burst and their evolution does not follow the theory. This makes their usage for determining the NS parameters questionable and casts serious doubt on the results of previous works that used similar bursts from other sources for analysis. 

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## Keywords

radiative transfer, stars: neutron, X-rays: bursts, X-rays: individual (4U 1724?307), X-rays: stars