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Studying Explosive Binary Systems with Nuclear Spectroscopy

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Type-I X-ray bursts are interpreted as thermonuclear runaways in the atmospheres of accreting neutron stars in close binary systems. These astronomical events exhibit brief, recurrent bursts of intense X-ray emission and represent some of the most frequent and violent stellar explosions to occur in our Galaxy. Recently, space-borne satellites such as the Rossi X-ray Timing Explorer (RXTE) and the Chandra X-ray telescope have produced a wealth of observational data on Type-I X-ray bursts, marking a new era of X-ray astronomy. However, in spite of these remarkable developments, many key questions about the exact nature of X-ray bursts remain, particularly in relation to the exact shape and structure of the observed light curves. As such, in order to fully exploit the remarkable achievements of X-ray astronomy, similar advances in our understanding of the underlying nuclear physics processes governing nucleosynthesis and energy generation are required.

X-ray bursts are powered by a sequence of nuclear reactions known as the rp (rapid proton) process - a series of (p,γ) captures and subsequent β^+ decays, synthesizing elements up to the Sn-Te mass region. This is a complex reaction network involving hundreds of nuclei from stable isotopes to the proton dripline. With recent advancements in computational power, it has become possible to construct detailed models of the rp-process nucleosynthesis and study the influence of nuclear reaction rate uncertainties. In particular, it has been shown that reactions around "waiting-point" nuclei have a significant effect on the resulting light curves. Specifically, the $^{48}\mathrm{Cr}(\mathrm{p},\gamma)^{49}\mathrm{Mn}$ and $^{59}\mathrm{Cu}(\mathrm{p},\gamma)^{60}\mathrm{Zn}$ reactions have been highlighted as being especially important. In this talk, spectroscopic studies of the nuclei $^{49}\mathrm{Mn}$ and $^{60}\mathrm{Zn}$ will be presented with a key emphasis on proton-unbound states that determine the rates of the astrophysical $^{48}\mathrm{Cr}(\mathrm{p},\gamma)^{49}\mathrm{Mn}$ and $^{59}\mathrm{Cu}(\mathrm{p},\gamma)^{60}\mathrm{Zn}$ reactions, respectively.

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