THE GAMMA–RAY SPECTRUM OF CLASSICAL NOVAE

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Abstract. We report on preliminary hydrodynamic simulations of thermonuclear runaways in the hydrogen-rich envelopes of accreting white dwarfs, leading to nova outbursts. A one-dimensional, Lagrangian, implicit, hydrodynamic code (Kutter & Sparks 1972) has been used to reproduce the *gross* features of a classical nova, from the onset of accretion, through the progress of the outburst up to the expansion stage, where significant mass loss takes place. Special interest is focused on the synthesis of ^{22}Na and ^{26}Al, for their interest in γ–ray line astrophysics. The γ–ray spectrum is built by means of a Monte Carlo simulation.

1. A nova outburst: from the onset of accretion to mass ejection

The evolution of a $1.25\,M_\odot$ carbon–oxygen white dwarf star, accreting matter at a rate of $\dot{M}_{acc} = 1.6\,10^{-8}\,M_\odot\,yr^{-1}$ has been computed. The accreted matter is assumed to be enhanced in CNO nuclei ($X = 0.46, Y = 0.13, Z = 0.41$) in order to power a fast nova. Detailed nucleosynthesis is obtained by following the evolution of 60 nuclei, ranging from ^{1}H to ^{28}Si, and linked through an updated network that includes more than 260 nuclear reactions. An envelope of $M_{env} \simeq 1\,10^{-5}\,M_\odot$ is accreted on top of the white dwarf star through a hydrostatic phase. As soon as the temperature at the bottom of the accreted envelope reaches $T_b \simeq 4\,10^7$ K, convection settles and extends gradually towards the star's surface. A peak energy generation of $1.4\,10^{15}\,erg\,g^{-1}\,s^{-1}$, followed by a peak temperature of $T_{max} \simeq 1.9\,10^8$ K are obtained, 529 yr from the beginning of the computations. At that time, convection reaches the surface, allowing the transport of short-lived β^+–unstable nuclei (^{13}N, ^{14}O, ^{15}O, ^{17}F) to the cool,

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outer layers. The ejection phase is powered by the delayed energy emission from the β^+−unstable nuclei. A mass $7.4\,10^{-6}\,M_\odot$ is ejected (72% of the envelope's mass) with velocities ranging from 958...4010 km s^{-1}. The maximum visual and bolometric magnitudes attained during the outburst are $M_{\rm vis} = -6.4$ and $M_{\rm bol} = -9.4$. The abundances, by mass, of ^{22}Na and ^{26}Al synthesized are $6.3\,10^{-4}$ and $9.8\,10^{-3}$, respectively.

2. Gamma-ray spectrum

During the nova outburst, several unstable nuclei are synthesized with abundances high enough to produce a strong γ−ray emission in their decay (Livio et al. 1992, Starrfield et al. 1992). These nuclei are divided into (i) short lived positron emitters which take part in the CNO cycle (^{13}N, ^{14}O, ^{15}O and ^{17}F) and (ii) ^{26}Al and ^{22}Na (Weiss & Truran 1990). Only the emission produced by the decay of ^{22}Na might be detectable by COMPTEL or INTEGRAL. The ^{22}Na decays following the chain $^{22}\mathrm{Na} \rightarrow {}^{22}\mathrm{Ne}$, producing a well defined γ−ray line at 1270 keV, and positrons which annihilate emitting 511 keV photon pairs. By means of a Monte Carlo code (Ambwani & Sutherland 1988), the spectra resulting from the interaction of these photons with the nova envelope have been calculated. The following physics is included in the code: (i) e^-−e^+ pair production, (ii) photoelectric absorption, (iii) non-conservative Compton scattering, (iv) e^-−e^+ annihilation, and (v) positronium formation. The calculations have been carried out at different times starting at 2300 s after the onset of the outburst. In all cases, the spectra are obtained by using the channels defined by the expected resolution of INTEGRAL and also, for comparison purposes, the spectra have been convolved with the COMPTEL (CGRO) spectral response. At 250 pc the continuum would not be detectable by COMPTEL, while INTEGRAL would detect part of it from several hours to 1 or 2 d after outburst. Concerning the 1270 keV line, an intensity of $2\,10^{-5}$ counts cm^{-2} s^{-1} would be obtained for our model for a nova at a distance of 1 kpc.

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