Cosmic radioactivity: Gamma-ray line observations with the INTEGRAL Satellite

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Gamma ray lines from cosmic sources display the action of nuclear reactions in cosmic sites. The gamma rays at such characteristic energies result from nuclear transitions following radioactive decays or high-energy collisions with excitation of nuclei. The gamma-ray line and its associated special continuum from the annihilation of positrons at 511 keV falls into the same energy window, although of different origin. We review the status of cosmic gamma ray spectrometry, reminding of the corresponding instruments and missions and future perspectives. We then present a discussion of recent results and the challenges and open issues for the future. This includes, specifically, the diffuse radioactive afterglow of massive-star nucleosynthesis in ^{26}Al and ^{60}Fe gamma rays, which is now being exploited towards the cycle of matter driven by massive stars and their supernovae, and towards understanding the current Galaxy and structure and morphology of its interstellar medium. Also the complex processes making stars explode as either thermonuclear or core-collapse supernovae are subject to studies through gamma-ray lines, in this case from shortlived radioactivities from ^{56}Ni and ^{44}Ti decays. Herein the non-sphericities that have recently been recognised as important are reflected, probably most-directly, through gamma-ray line characteristics. We will also discuss how we should relate to the above the distribution of positron annihilation gamma ray emission with its puzzling bulge-dominated intensity distribution, which is measured through spatially-resolved spectra. These indicate that annihilation conditions may differ in different parts of our Galaxy, and helps to reveal the complex paths recycling matter from nucleosynthesis sources to next-generation stars.