Contribution ID: **104** Type: 海报展示

Calculation of response matrices for GRID CubeSat gamma-ray detectors

摘要

空间分布式伽马射线暴探测网（天格计划）是一个旨在监测空间高能瞬变源的项目，该项目使用紧凑型的伽马射线探测器作为微纳卫星的有效载荷，用多个卫星组网进行观测。为了从探测器测得的能量信息重建出所观测到的瞬变源的能谱，我们需要详细了解探测器的响应特性，该响应特性是通过响应矩阵描述的。为此，我们计算了已发射的天格计划探测器的响应矩阵，并使用在轨观测数据验证了它们的准确性。我们首先使用 Geant4 进行蒙特卡罗模拟，计算了不同条件下伽马射线光子在探测器中的能量沉积，然后根据地面标定得到的能量分辨率对模拟结果进行校正，以最终得到响应矩阵。此外，我们还建立了一个用于插值的响应矩阵数据库，以便于快速生成对应于任何入射方向的响应矩阵。我们通过对天格计划探测器在轨观测到的伽马射线暴进行能谱拟合，验证了响应矩阵的正确性。基于上述计算方法，我们在发布天格计划科学数据的同时提供响应矩阵生成工具，从而有效提高对天格计划观测数据开展科学分析的效率。

关键词

空间仪器；伽马射线探测器；能谱响应

Abstract

The Gamma-Ray Integrated Detectors (GRID) mission aims to monitor high energy transients in space with multiple CubeSats carrying compact gamma-ray detectors as payloads. Reconstructing the energy spectra of detected bursts from the measured detector output energies requires detailed knowledge of the detector response characteristics, which are represented by response matrices. We calculate the response matrices for each GRID detector that has been launched and verify their accuracy using in-orbit data. In this work, Monte Carlo simulations with Geant4 are employed to calculate the energy deposition of gamma-ray photons in the detectors under various conditions. The response matrices are then generated by adjusting the simulation results based on the energy resolution obtained from on-ground calibrations. In addition, we establish a database of response matrices designed for interpolation, enabling efficient generation of matrices for any incident direction. The generated response matrices are verified through spectra fittings of gamma-ray bursts (GRBs) observed by GRID detectors in orbit. Building on the calculation method described above, we provide a response matrix generation tool alongside the release of GRID scientific data, enabling convenient scientific analysis for the GRID mission.

Keywords

space instrumentation, gamma detectors, spectral responses

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Session Classification: 海报展示

Track Classification: 02 海报展示: 海报展示