PySPI: A python analysis framework for INTEGRAL/SPI

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Software

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Summary

PySPI is a newly developed pure python analysis framework for Gamma-Ray Burst (GRB) data from the spectrometer (SPI) onboard the International Gamma-Ray Astrophysics Laboratory (INTEGRAL). The INTEGRAL satellite is a gamma-ray observatory hosting four instruments that operate in the energy range between 3 keV and 10 MeV. It was launched in 2002 and is still working today. The main goals of PySPI are to provide an easy to install and develop analysis software for SPI, which includes improvements on the statistical analysis of GRB data.

At the moment PySPI is designed for transient sources. One interesting example of transient sources are GRBs, which are extremely bright but short flashes of Gamma-Rays, with a typical duration between a few ms and a few hundred seconds. They are believed to be produced by the collapse of massive stars and mergers of compact objects, like for example neutron stars. In the future we plan to add support for other types of sources than transients, such as persistent point sources as well as extended emission.

Statement of need

The main analysis tool to analyze SPI data up to now is the "Off-line Scientific Analysis" (OSA) (Chernyakova et al., 2020), which is maintained by the INTEGRAL Science Data Centre (ISDC). While it is comprehensive in its capabilities for manipulating data obtained from all instrument on-board INTEGRAL, it exists as an IDL interface to a variety of low-level C++ libraries and is very difficult to install on modern computers. While there are containerized versions of OSA now available, the modern workflow of simply installing the software from a package manager and running on a local workstation is not possible and often students rely on a centralized installation which must be maintained by a seasoned expert. Moreover, adding more sophisticated and/or correct data analysis methods to the software requires an expertise that is not immediately accessible to junior researchers or non-experts in the installation of OSA. Also due to the increased computational power that is available today compared to that of 20 years ago, many of the analysis methods can be improved.

PySPI addresses both these problems: It is providing an easy to install software, that can be developed further by everyone who wants to participate. It also allows Bayesian fits of the data with true forward folding of the physical spectra into the data space via the response. This improves the sensitivity and the scientific output of GRB analyses with INTEGRAL/SPI.

SPectrometer on INTEGRAL (SPI)

SPI is a coded mask instrument covering the energy range between 20 keV and 8 MeV. It consists of a detector plane with 19 Germanium detectors and a mask plane 1.7 meters above the detectors with 3 cm thick tungsten elements. The mask produces a shadow pattern on the detectors depending on the source position. This information can be used to construct an image from an observation. Also SPI has an excellent energy resolution of 2.5 keV at 1.3 MeV, which makes SPI an ideal instrument to analyze fine spectral features, such as lines from radioactive decays (Vedrenne, G. et al., 2003).

Procedure

To analyze GRB data, PySPI accepts inputs such as the time of the GRB and the spectral energy bins that will be used in an analysis. With this information, it automatically downloads all the data files required for a specific analysis and constructs a response as well as a time series for the observation that contains the GRB time. The time series can be used to select active time intervals for the source, and time intervals before and after the GRB signal for background estimation. After this has been done, a plugin for `3ML` (Burgess et al., 2021; Vianello et al., 2015) can be constructed. This allows for all the benefits the 3ML framework offers like the modeling framework `astromodels` (Vianello et al., 2021), joint fits with other instruments, many different Bayesian samplers and much more. In the documentation there is an example for this workflow procedure.

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