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150 - Oral - Instrumentation: Space Missions II

150.01 - Metorology for Measuring Custom Periodicities on Diffraction Gratings

Spectroscopy is a fundamental exploratory tool in the study of astronomy to investigate plasma components, density, and temperature in stars, planets, interstellar material, etc. A diffraction grating is an essential spectroscope component exhibiting a periodic structure that diffracts light into constituent wavelengths.Transmission gratings and reflection gratings are two types of diffraction gratings. The reflection grating normally shows strength in higher diffraction efficiency and a wider range of spectral coverage. Usually, the reflection grating is patterned with parallel grooves with a constant period. However, in some special cases, the patterned grooves are designed with custom orientations, which may cause a variation of the period of as little as a few nanometers over tens of millimeters of groove length. To qualify the fabrication method of these special reflection gratings, we require an accurate and easy mapping method for groove period. Accurate groove period distance measurement (~ 1 nm) and large scanning area (100 mm x 100 mm) are two requirements for mapping the groove density of a custom grating. Scanning electron microscopy (SEM), scanning probe microscopy (SPM), and optical interferometry are three traditional technologies for nano metrology. Each of the three methods just described falls short of achieving both requirements. In addition, there are some previous studies about metrology for other grating groove density measurements. However, those methods are designed for parallel grooves with constant groove density or a small variation of the groove density. To achieve the requirements, we developed a new, inexpensive, bench-top method for measuring groove period over large areas. This method uses the positions of reflected light and diffracted orders to determine the groove density. Based on a simple geometry, we can calculate the grating period by accurately measuring the angles and using a stable laser beam. Our method can reach the same accuracy on the parallel groove gratings and it can also resolve custom-period gratings. I will present this new method in measuring the groove density distribution of gratings. This method has accuracy in measuring absolute groove density, has the ability to resolve a large variation in groove density, and can easily be used to scan a large area of the grating. Three gratings, each with a unique pattern, were measured with this method. The test configuration of these three measurements and a walkthrough of the data reduction process will be explained.

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150.02 - Characterization of a Single Photon Sensing Detector for Astrophysics

We report characterization results for a new single photon sensing detector. The megapixel device is made of silicon and is sensitive to UV and optical light. Unlike other single photon sensing detector arrays, such as those based on avalanche photodiodes, its pixels have high fill factor and can distinguish photon number. It can operate at room temperature, as opposed to deep cryogenic temperatures required by superconducting single photon sensing detectors. We present measurements of read noise, dark current, persistence, and quantum efficiency. We compare the results to requirements of astrophysics missions. Eric Fossum, and collaborators at Dartmouth College, designed and initially characterized the detector. Gigajot Technology made the camera. The RIT Center for Detectors obtained the data presented in this paper. This work is funded by a NASA Strategic Astrophysics Technology grant.

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150.03 - Direct High Contrast Imaging with Charge Injection Devices.

Charge Injection Devices (CIDs) have the capability to perform direct high contrast imaging with ratios approaching 1:1 billion. Individual pixel control allows regions of interest to be addressed rapidly and independently from the remainder of the array. A 32-bit register enables storage of up to log(9.6) values per pixel, and the latest generations of CID have demonstrated 5.8 electrons rms noise with 128 non-destructive reads. When combined with effective PSF suppression techniques, CIDs therefore become interesting prospects for obtaining direct images from a host of high contrast ratio scenes, including exoplanets. Results from sub-optimal ground-based astronomical observations with a CID will be presented in which direct contrast ratio imaging in excess of 1:20 million was achieved. In addition, for CIDs to be used on future space-telescopes they must be flight qualified in the space environment and shown to be at the appropriate Technology Readiness Level (TRL). We will therefore also report on an 8-month CID technology demonstration mission that achieved TRL-8 using the Nano-Racks External Platform on-board the International Space Station.

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150.04 - A novel approach to map 511 keV positron annihilation signal in our galaxy

Emission from electron-positron annihilation at 511 keV was the first extrasolar gamma-ray line ever detected. Despite more than 30 years of theoretical and observational progress, the origin of the positron population has yet to be identified, with potential candidates ranging from microquasars and X-ray binaries to annihilation or decay of dark matter particles. At energies between 200 keV and 2 MeV, the largest source of instrumental background are secondary protons, neutrons, and photons produced by the spacecraft when it is irradiated by cosmic rays in a space environment. This background is proportional to the amount of mass around the detectors. This is specially the case for 511 keV line astronomy, as positrons emitted by beta+ decays in the passive spacecraft material will produce a background of 511 keV gamma rays that is indistinguishable from astrophysical positron-annihilation photons. An optimal mission design would maximize the active mass of the spectrometer to increase the gamma-ray collection efficiency while minimizing the total weight of the surrounding spacecraft to reduce local positron production by cosmic rays. This is naturally accomplished in small-satellite missions of the CubeSAT or SmallSAT class, for which industrial partners have developed in the last decade small and lightweight buses, batteries, communications and attitude-control systems. A small-satellite mission equipped with a HPGe spectrometer could have the same collection area as INTEGRAL, the ESA-led gamma-ray mission that has produced the most-sensitive map of galactic 511 keV emission, with more than an order-of-magnitude improvement in signal-to-noise ratio due the reduction in overall spacecraft mass. In this design, the active HPGe crystal represents > 40% of the total spacecraft mass, compared to < 0.6% in current satellites like INTEGRAL. The mission concept uses the Earth-occultation technique to map changes in the signal rate to the occultation and re-appearance of astrophysical sources by the Earth as the spacecraft follows its orbit. A full payload design including a cooling system, charged-particle anti-coincidence shield, and readout electronics will be presented.

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150.05 - An update on the Off-plane Grating Rocket Experiment

The Off-plane Grating Rocket Experiment (OGRE) is a suborbital rocket payload that will fly a soft X-ray grating spectrometer. With a performance goal of R>2000 at select energies in its 10-55 Angstrom bandpass of interest, the spectrometer seeks to obtain the highest resolution soft X-ray spectrum to date. This performance will give an unprecedented look at the line-dominated soft X-ray spectrum of its target - Capella. Critical to performance goal of the spectrometer are the performance of each of its three components: mono-crystalline silicon optics developed by NASA Goddard Space Flight Center, X-ray reflection gratings from The Pennsylvania State University, and electron-multiplying CCDs developed by XCAM Ltd. & The Open University. We report on the progress of each of these components as well as on the payload as a whole.

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150.06 - Concept study of a small Compton polarimeter to fly on a CubeSat

Application of CubeSats in astronomical observations has been getting more and more mature in recent years. Here we report a concept study of a small Compton polarimeter to fly on a CubeSat for observing polarization of soft gamma-rays from a black-hole X-ray binary, Cygnus X-1. Polarization states provide very useful diagnostics on the emission mechanism and the origin of those gamma rays. In our study, we conducted Monte Carlo simulations to decide the basic design of this small polarimeter. Silicon detectors and cerium bromide scintillators were employed in this study. Our result indicates that it is feasible to perform this polarization measurement for Cygnus X-1 with such a small instrument to fly on a 3U CubeSat. We will proceed to have a more realistic design and look for opportunities of a CubeSat mission.

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