Universität Zürich[UZH]

Physik-Institut

Innovative Instrumentation for Cosmology

Soares-Santos Lab

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The Soares-Santos lab is focused on improving the scientific outcomes of future cosmological surveys with state-of-the-art instrumentation. We are developing subsystems for the next generation of galaxy surveys. These instruments will change our understanding of the universe by precisely measuring its contents and structure. If you are interested in building the next generation of astronomical instrumentation, join us!

Fig.1: Current PhD student Sean MacBride commissioning the main camera for the Large Synoptic Survey Telescope (LSST)

Fig. 2: Current PhD student Isaac McMahon observing with the Dark Energy Spectroscopic Instrument (DESI) at Kitt Peak National Observatory in Arizona, USA.

Image sensors for astronomy

Background

Imaging is one of the primary tools used by astronomers to study the universe. The sensitivity of astronomical imagers is directly linked to the scientific outcomes of an astronomical survey. Sensor features such as full-well, quantum efficiency, readout efficiency, and point-spread function directly impact galaxy survey outcomes, and therefore are critical to ensuring that astronomical instruments meet their scientific targets.

Cutting edge sensors

Most modern sensors in astronomy use charge-coupled devices (CCDs), but recent advances have led to a suite of new options. Complementary metal–oxide–semiconductor (CMOS) sensors have long been used in commercial cameras, but only recently have reached noise levels appropriate for astronomy. Additionally, new readout schemes for CCDs known as 'Skipper' CCDs have recently been shown to have reasonable readout times to complement their low-noise potential.[5]

Previous work with image sensors

DECam

Prof. Marcelle Soares-Santos played a key role in the construction and commissioning of the Dark Energy Camera (DECam). Her contributions include camera verification and construction of a full-sized telescope simulator for full system testing and integration.[3]

LSSTCam

Johnny Esteves (PhD 2024, University of Michigan) has contributed to the verification and analysis of the LSST Camera (LSSTCam), including studying the tree rings in the LSSTCam focal plane.[1] Johnny is currently a Postdoc at Harvard University.

Sean MacBride is currently a PhD student at UZH. Sean is contributing to the commissioning of LSSTCam at Cerro Pachón, and is leading the re-verification of LSSTCam. In addition, he has characterized the picture-frame response in the LSSTCam sensors, including manufacturer-specific defect behavior.[2]

Spectroscopic galaxy surveys

Background

Astronomers use the electromagnetic spectrum to study objects in space, using spectroscopic data to measure objects' contents, ages, and spatial distributions. The precision of spectroscopic surveys is constrained by the characteristics of the focal plane, and the performance of the spectral imagers. Recent advances in focal-plane spectra acquisition have introduced an era of massively-multiplexed spectroscopy, advancing rapidly past slit spectroscopy.

Robotic positioners

The first instance of multiplexed spectroscopy was the Sloan Digital Sky Survey (SDSS), which utilized round aluminum pieces with holes in them to plug optical fibers that collect the light from each astrophysical object. The optical fibers fed to a spectrograph that analyzed the light. The Dark Energy Spectroscopic Instrument (DESI) iterates on this design, utilizing robotic positioners with two arms to place fiber optics in precise locations on the focal plane of the Mayall Telescope. New positioner designs aim to increase the fiber density across the focal plane to increase science returns.

Previous work with robotic positioners

DESI

The robotic positioners in DESI experience a common failure mode in ~10% of the focal plane. Our group set out to characterize and resolve this failure mode, called the 'linear-phi' problem. While testing this failure, we built a telescope simulator to test robotic positioner performance in different physical orientations. Despite the failure mode not being replicated and resolved in a laboratory setting previously, our group conducted tests that resulted in the first laboratory replication and resolution of this error.

Piezoelectric spines

An alternate design of the robotic positioners utilizes piezoelectric materials to tilt metal spines with fiber optics. Tilting spines offer high spatial precision with the downside of off-axis light losses. Our group led engineering efforts to study tilting spines as part of a pilot study for new positioner technology in next-generation spectroscopic surveys.[4]

Upcoming Projects

We have several projects planned and ongoing in our group

Robotic positioners

- Studying fiber-angle while exercising the positioner
- Characterizing focal-ratio degradation in robotic positioners
- Quantifying the performance of different robotic positioner designs
- Validating robotic-positioner designs for next-generation spectroscopic instruments

Image sensors

- Set up an optical lab for testing advanced image sensors
- Characterize a known image sensor
- Test novel image sensors for astronomical applications
- Characterization of sensors for non-optical astronomical applications

If you are interested in building the next generation of instrumentation for precision astronomy, send us a copy of your CV for review.

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