

PARTICLE ASTROPHYSICS & COSMOLOGY

FACULTY

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SLAC's particle astrophysics program has greatly expanded in recent years first with involvement in the USA mission, then the approval of the joint DOE/NASA GLAST mission, and now the startup of the new Kavli Institute for Particle Astrophysics and Cosmology (KIPAC). KIPAC is co-located at SLAC and on campus. The SLAC facility will be located in the Fred Kavli Building when construction is completed in fall 2005. This building will also host the Pierre R. Schwob Computing and Information Center where state of the art graphics and analysis facilities will be used to analyze astronomical observations and numerical simulations. Six months later, in spring 2006, the campus wing of KIPAC will move into a new building, adjacent to the present Varian building which KIPAC will share with the Hansen Experimental Physics Laboratory (HEPL).

GLAST MISSION

GLAST (Gamma Ray Large Area Space Telescope) is a major space astronomy telescope due for launch in early 2007. It is SLAC's first venture into the construction of large scale particle-astrophysics hardware. NASA selected SLAC to contribute the major instrument on GLAST, the Large Area Telescope or LAT. It will monitor the gamma ray sky from energies of roughly 10 MeV to over 100 GeV and will observe pulsars, quasars, gamma ray bursts and other exotic cosmic objects. It will follow up the discoveries made by the

Energetic Gamma Ray Experiment Telescope or EGRET, which flew earlier on the Compton Gamma Ray Observatory. GLAST has the discovery potential to see decay products from the annihilation of dark matter particles.

GLAST measures the energies and arrival directions of gamma rays from astronomical sources by allowing them to convert into electron-positron pairs and following these particles using high precision, silicon strip trackers (adapted from detectors used in particle physics) and a highly segmented Cesium Iodide Calorimeter. It does this in the presence of a large cosmic ray background using sophisticated, anti-coincidence techniques.

As the launch date approaches, the focus will shift from the construction and integration of the telescope to the data analysis and the observing plan, which will involve many other telescopes operating throughout the electromagnetic spectrum. By summer 2007, GLAST should be making major discoveries about Nature's highest energy sources. This provides a wonderful opportunity for new graduate students.



Gamma Ray Large Area Space Telescope (GLAST).

THE KAVLI INSTITUTE FOR PARTICLE ASTROPHYSICS AND COSMOLOGY

In March 2003, SLAC and the Stanford Physics and Applied Physics departments inaugurated a new, independent research laboratory known as the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC). KIPAC will be home to a rapidly growing research effort in this field. Over twenty new researchers have already started working at Stanford, and there should be nine new faculty members leading research groups within KIPAC by the end of the decade.

KIPAC has been formed with a view to consolidating and increasing Stanford University's involvement in particle astrophysics and cosmology. It is also intended to provide links between the various groups involved in, for example, microwave background observation, neutrino astrophysics, dark matter detection, experimental gravitation, theoretical physics, and more. KIPAC operates on four closely related fronts: theory, experiment, computation, and observation.

THEORY

Current theoretical interests of the group include dark matter, general relativity, gravitational lensing, inflationary cosmology, gamma ray bursts, physical processes in clusters of galaxies, pulsars, accretion disk astrophysics, ultra high energy cosmic rays and neutron star astrophysics. Theoretical research within KIPAC involves collaboration with the particle theory group at SLAC, the Stanford Institute for Theoretical Physics and the Center for Space Science and Astrophysics as well as observers and experimental astrophysicists. Stanford is a particularly good environment for theorists who like to make connections between different research endeavors.

EXPERIMENT

The experimental astrophysics effort centers around several new projects. These include the Large-Area Synoptic Survey Telescope (LSST) which is a proposal to construct an 8m class ground-based telescope that will survey three quarters of the visible sky every few days. It will contain a giant camera with a



GLAST Test Bed.

detector containing over 3.8 billion pixels that will be read out every ten seconds. SLAC's role in this project, which should see first light in 2012, is to lead the construction of the camera. This is a major undertaking. The principal, scientific goal of LSST involves measuring the weak distortions of the images of distant galaxies, induced by intervening large scale distributions of mass and influenced by the temporal evolution of the dark energy background. The LSST will also open up a lot of discovery space through its monitoring of all classes of variable and transient cosmic sources.

Another project to which KIPAC is anticipated to make a major hardware contribution is the Super Nova Acceleration Probe (SNAP). This instrument is designed primarily to measure the acceleration of the Universe by observing the rate of dimming of supernovae with increasing distance. It will also contribute greatly to our understanding of gravitational lensing.

In addition to these two projects, KIPAC physicists intend to build hardware for several proposed X-ray telescopes including, NuSTAR, NeXT, EXIST, Constellation-X and POGO. Most of these projects contain hardware components that can be completed within the five-year span of a graduate student career and provide excellent opportunities for PhD research.

COMPUTATION

The LSST will present astrophysicists with a major analysis challenge. It is projected to generate over 30 Petabytes of data over its lifetime. This dataset will have to be archived in such a way that it can be accessed, disseminated and mined efficiently and its very size makes this a formidable undertaking to contemplate. Fortunately, the computer scientists at SLAC, who are currently involved in the BABAR experiment, have much relevant experience and they plan to collaborate with KIPAC in learning how to work productively in this high data environment. A quite different style of computing, that is also performed at SLAC, involves large-scale numerical simulation of neutron stars, accretion disks, and the Universe at large. These calculations provide the best way we have to understand the nonlinear and multi-scale physics that is too complex to be addressable using analytical techniques. Many of these simulations are integrated directly into the design and prosecution of large astronomy projects including those discussed above. Students with a joint background in astrophysics and computer science will find major opportunities to combine astrophysics, numerical expertise and hardware.

OBSERVATION

KIPAC astrophysicists also carry out an extensive observing program using data acquired by Hubble Space Telescope, the Chandra X-ray Observatory, the XMM-Newton X-ray telescope, and other publicly accessible facilities as well as the Hobby-Eberly telescope for which Stanford is a partner. Recent results have included findings on clusters of galaxies, microlensing of stars in external galaxies, neutron star spectroscopy and binary pulsars. GLAST observations are likely to be a major source of data from 2007 onward.

EDUCATION AND RESEARCH

Particle Astrophysics and Cosmology students are admitted into the Physics Department and are required to take a sequence of physics courses administered by the Department. Students participating in research with KIPAC faculty advisors may be required to take additional coursework in astrophysics. Students will have the opportunity to participate in an exceptionally broad, though integrated, sequence of seminars and colloquia on current research topics including astrophysics, cosmology, gravitation, instrumentation, and theoretical physics. They are expected to participate in and benefit from the complementary research programs at SLAC and on campus.