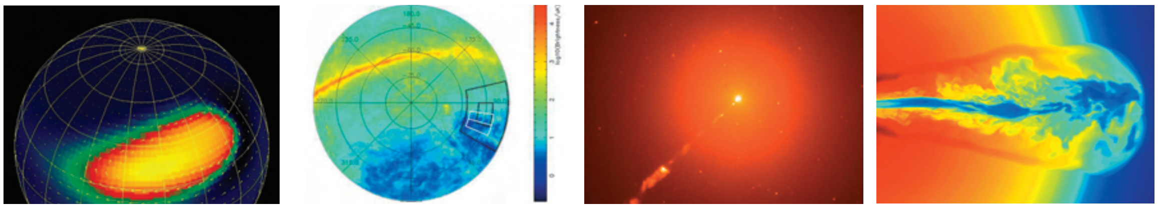
THE KAVLI UNIVERSE

Kavli Building Dedication – March 17, 2006

From the Fred Kavli Building on the SLAC campus and the physics buildings on Stanford's main university campus, KIPAC researchers seek solutions to some of today's most fascinating and challenging problems in astrophysics and cosmology.



In the deep reaches and extreme cosmic environments of space, we can observe exotic processes impossible to explore on earth. From the colossal magnetic field of a neutron star to the astonishing energies of relativistic jets and gamma-ray bursts, these discoveries allow us to test fundamental physics. Every year KIPAC and other institutes around the world add significant, fresh discoveries to this list.

–above from left to right–

The spreading of a thermonuclear burning hotspot on the surface of an accreting neutron star during an X-ray burst.
Simulation courtesy of Anatoly Spitkovsky.

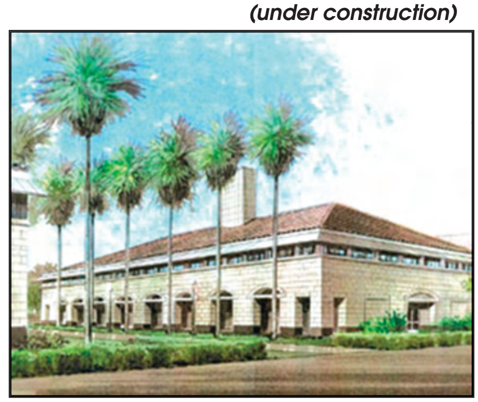
This January 2005 test data from QUaD shows the polarization properties of the Cosmic Microwave Background.
Image courtesy of Sarah Church

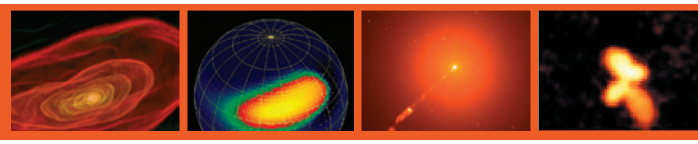
A Near infrared image of the central region of the giant elliptical galaxy M87, 50 million light years away.
Image courtesy of Edward Baltz and made using the Hubble Space Telescope WFPC2 camera.

A relativistic jet breaks out of a massive star. In this computer simulation.
Simulation courtesy of Weigun Zhang

Fred Kavli Building

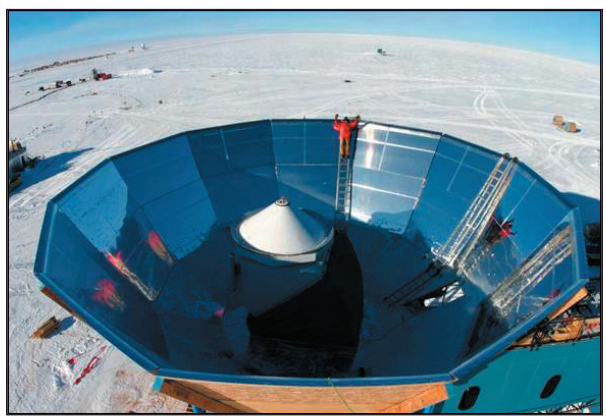
Physics-Astrophysics Building (under construction)





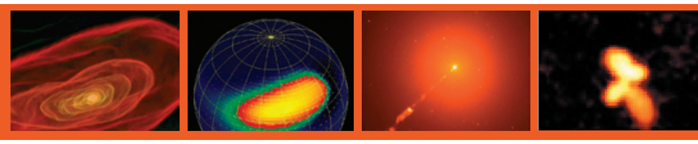
Astrophysicists are not merely cartographers of the universe; they are also historians. In order to understand the most fundamental truths about the world around us today, cosmologists look into the past. The universe sprang into existence thirteen and a half billion years ago in a burst of energy and light called the Big Bang. It has since evolved, expanding and cooling to form what we observe today. The Cosmic Microwave Background (CMB), the remnants of this hot, dense epoch, is visible to researchers as a nearly uniform glow permeating the universe. The existence of the CMB is widely considered proof of the Big Bang.

Current research, such as the South Pole's QUaD telescope, seeks to discover more about the universe's first moments and how the universe transformed into everything we observe today.



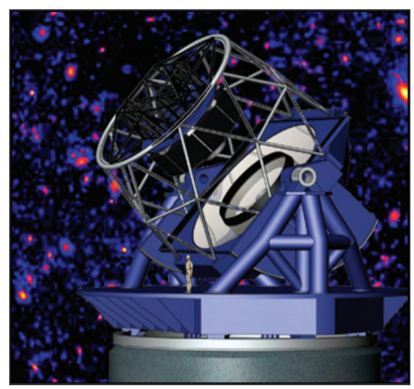
The QUaD receiver was installed in the summer of 2004 to help reveal the intricacies of the early universe.

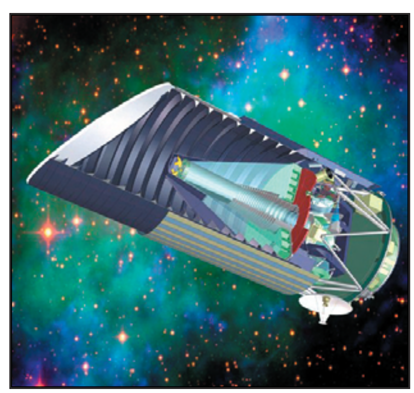
KIPAC investigator Sarah Church and Pierre Schwab at the South Pole.



Over the past seventy years, astronomers concluded that luminous matter—everything we can see and everything of which we are made—accounts for just four percent of the universe. Seventy-two percent of the universe is called dark energy, but we do not yet understand its nature. An additional 24 percent of the universe is in the form of dark matter. Currently, the best explanation for dark matter requires the existence of a different type of matter that is weakly interacting and stable over the age of the universe.

The CDMS project, part of which is based at Stanford, attempts to measure directly the expected but rare interactions between dark matter and ordinary matter. In addition, KIPAC and SLAC researchers are hard at work designing a camera for the Large Synoptic Survey Telescope (LSST) whose primary use will be to determine the properties of dark energy and dark matter through measuring distortions in the images of distant galaxies. LSST will be followed by the complimentary orbiting telescope SNAP (the SuperNova Acceleration Probe), which will study dark energy using supernovae observations.



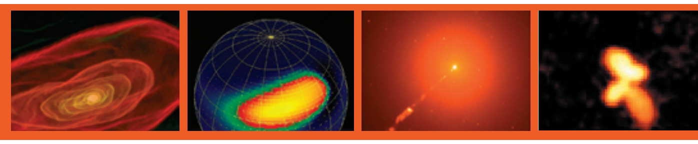


–clockwise from top left–

Northern Minnesota's Soudan Mine, where CDMS detectors search for the signature of Weakly Interacting Massive Particles (WIMPs).

Steve Kahn is leading a proposal to construct the camera for the Large Synoptic Survey Telescope (LSST).

A rendering of the Supernovae/Acceleration Probe.



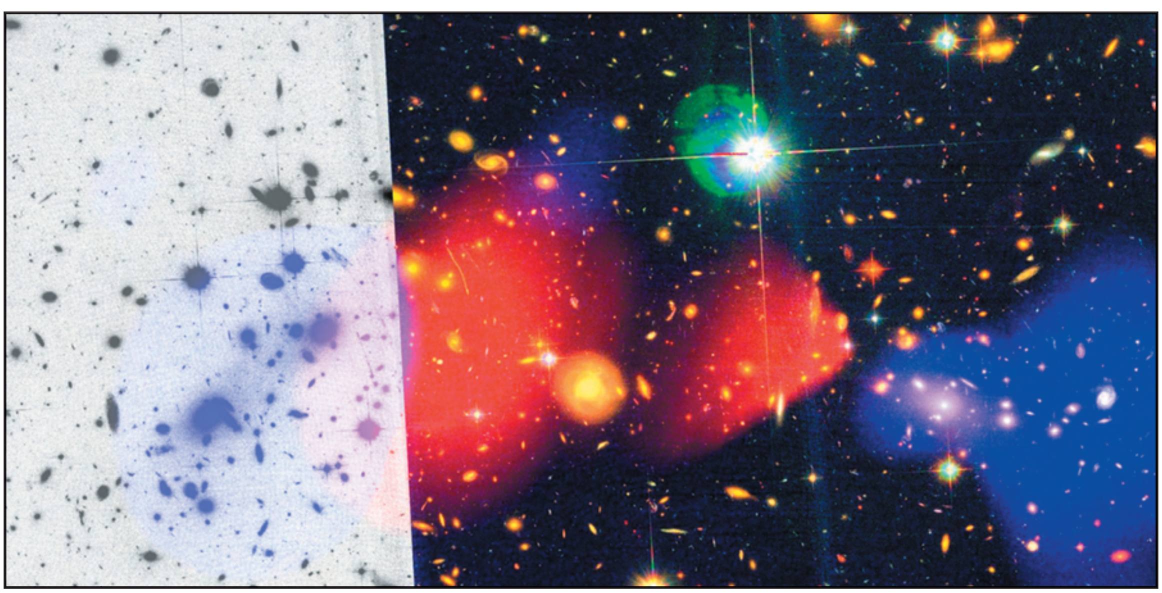
Many galaxies congregate in groups of 1,000 or more, called clusters. By studying these clusters, it is possible to learn about the evolution of the universe. We study the bending, or gravitational lensing, of light by massive galaxies at optical and radio wavelengths. Hot plasma in the space between galaxies can also be studied using X-rays and microwave background radiation.

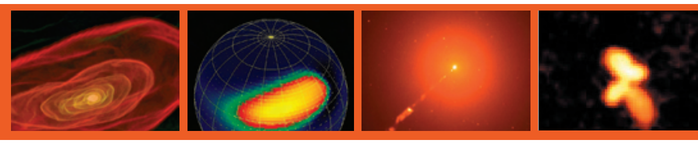
–from top to bottom–

Galaxy cluster A1689 as seen with the Hubble Space Telescope. The bright yellow galaxies in this image reside in the cluster, while the faint blue galaxies can be seen in the background highly distorted by the strong gravitational field associated with the dark matter in the cluster. Clusters such as these are big enough to be a representative sample of the contents of the universe, a fact utilized by Steve Allen in his work on cosmological parameter estimation.

The bullet cluster as seen with ACS on the Hubble Space Telescope (see also back cover), is shown in red, and the inferred location of dark matter is shown in blue.

Images courtesy of Marusa Bradac and Phil Marshall.





Individual galaxies held captive by concentrations of dark matter are the major constituents of the universe. Most galaxies, including our own, contain massive black holes in their cores. These black holes often create spectacular jets—cosmic linear accelerators—of relativistic electrons and positrons. GLAST, the Gamma-ray Large Area Space Telescope, will launch in 2007 to study these jets to help understand their formation.

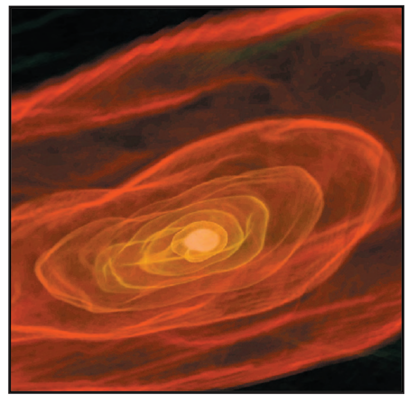
Galaxies contain massive amounts of gas and millions of compact objects, including stars like our sun as well as neutron stars. We study neutron stars to understand the behavior of matter and radiation in the strong gravity, extreme density, and giant magnetic field characteristic of neutron stars.

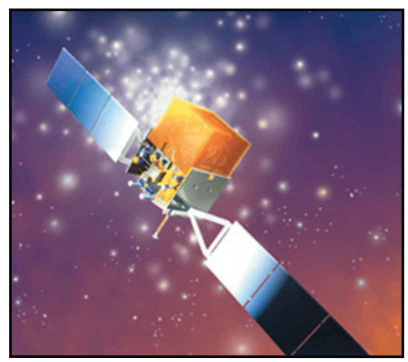
–from top to bottom–

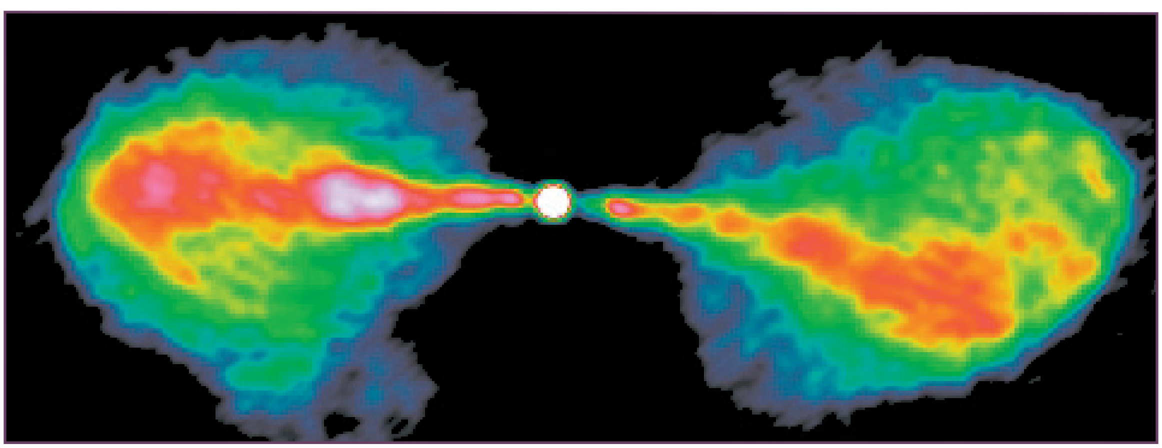
A simulation of the formation of the first star at the center of a cloud of gas. Before galaxies could form, the first stars in the universe were born between one and two million years after the Big Bang.
Image courtesy of Tom Abel.

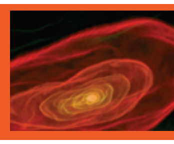
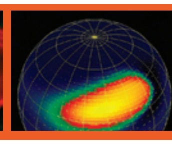
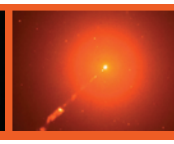
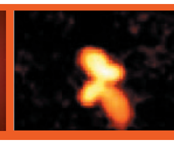
A rendering of the Gamma-Ray Large Area Telescope (GLAST)

This radio image shows a twin pair of relativistic jets released from the center of nearby galaxy NGC4261, known to host a super-massive black hole (in white) at its core.
Image courtesy of Teddy Cheung using data from the Very Large Array.



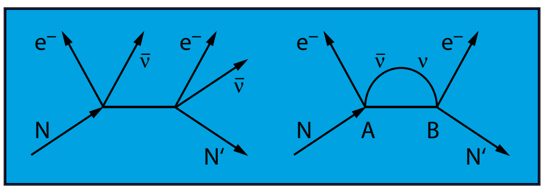


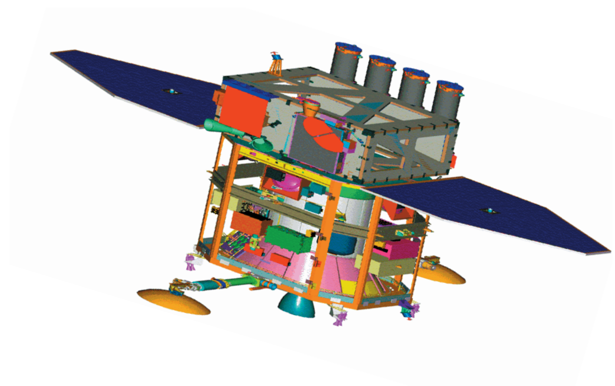


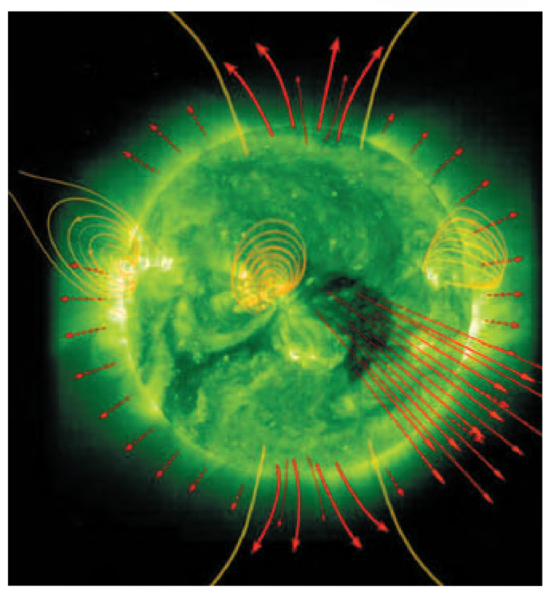





Normal stars, like our sun, may at first seem less dramatic than neutron stars, but they too offer opportunities to understand basic physics. The magnetic field which pervades the cosmos is responsible for much of the powerful and explosive activity we observe. There is no better laboratory to study the erratic and tortuous behavior of magnetic field lines than the solar corona, which is regularly observed with satellites like TRACE and SDO.

In addition, neutrinos stream freely from the core of the sun, carrying away nearly as much energy as the sun radiates in light. In order to understand the properties of neutrinos and to get at the very nature of mass itself, Stanford researchers are embarking on a laboratory experiment, called EXO, to weigh neutrinos and determine whether or not they are their own antiparticles.







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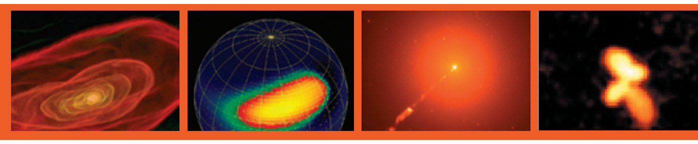
Giorgio Gratta and his colleagues are planning the Enriched Xenon Observatory (EXO) to weigh neutrinos by comparing the rates of two subatomic processes as depicted here. Their conclusions will help us understand how the sun works.

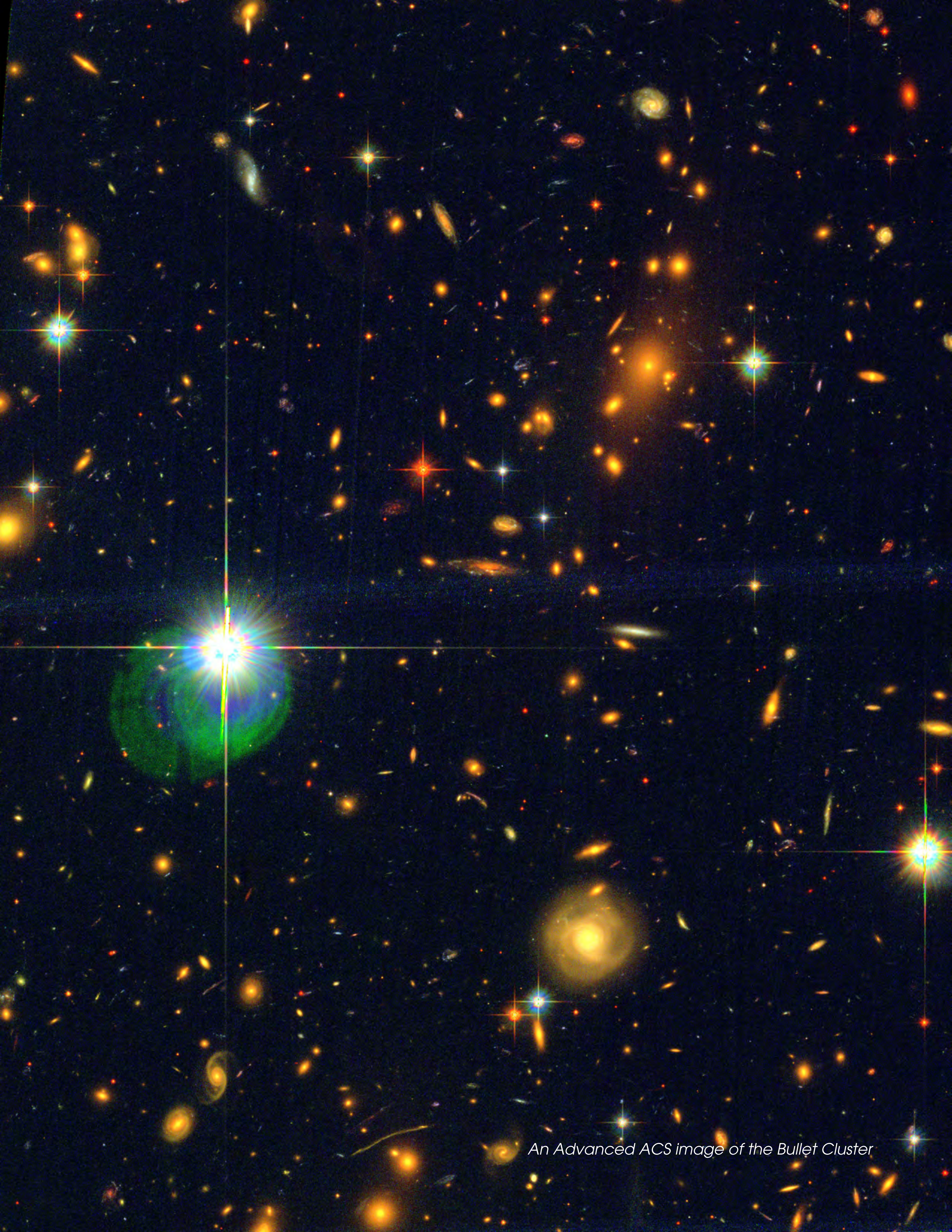
The Solar Dynamics Observatory (SDO) will be launched in 2008 with the Stanford-Lockheed Helioseismic and Magnetic Imager instrument.
The HMI investigation, led by Philip Scherrer, will observe the solar interior and will measure magnetic fields necessary to understand the corona. HMI is a next generation instrument following from the successful NASA/ESA SOHO/MDI Stanford-led investigation and the TRACE Lockheed-Martin led mission.

This ultraviolet image of the sun's corona shows sample magnetic field lines. The Stanford SOHO Michelson Doppler Imager instrument provides magnetic field measurements which are combined with EIT images to study the corona.



KIPAC researchers link local phenomena to processes that we observe in the young and distant universe to reveal the innermost workings of the physical world.

Members of KIPAC



An Advanced ACS image of the Bullet Cluster