

## Summary of Scientific Results – 2005

Subaru Telescope continues to expand the boundaries of astronomical knowledge and cosmological understanding. Another busy year of observations brought discoveries of interest to subjects ranging from Solar System bodies to stellar composition and distant dark matter. Subaru continues to lead the path of discovery for large 8m-class earth-based telescopes.

One of the most globally exciting events, especially in the world of astronomy, was NASA's Deep Impact Mission. Subaru and many other telescopes on Mauna Kea participated in the once-in-a-lifetime spectacle. On July 4<sup>th</sup>, a space probe impacted comet 9P/Tempel 1 with a huge chunk of copper traveling at 23,000 miles per hour. This was done to break up the comet's crusty surface to learn about its dust and ice components and so that large telescope's like Subaru could examine the impact effects. Subaru identified a complex mix of silicates, water, and organic compounds in the 1000 tons of quickly-dissipating ejecta. The materials revealed striking similarities between two different families of comets (Periodic versus Oort Cloud) where none was thought to occur, mostly where the comets originally formed.

While we're discussing events within the Solar System, scientists using data from Subaru showed that the size distribution of objects in the asteroid belt match the size distribution of craters on the Moon. Additional studies found twelve new moons around Saturn, bringing the total to 46, and also discovered crystalline water ice in a distant Kuiper Belt object, Quaoar.

The search for planets outside our Solar System motivates much of modern astronomy. Although over 270 planets have been found through indirect methods, being the first to directly image an extrasolar planet is one of the primary goals of Subaru. This year, astronomers discovered an unusual extrasolar planet about the same mass as Saturn but significantly smaller in size. The planet shows evidence that core accretion is a viable mechanism of planetary formation, and implies that terrestrial-type planets (i.e. Earth) should exist in abundance in other planetary systems. Another group of astronomers on the quest for extrasolar planets discovered the coolest and lightest of brown dwarfs orbiting nearby young stars. It is only 40 times the mass of Jupiter and 250 times fainter than its companion star DH Tauri. These findings show that Subaru is on the right path of planetary discovery.

Subaru continued its study into the strange and exciting world of hypernova and gamma ray bursts (GRB). Simply, a hypernova is a hyper-energetic supernova of an extremely massive star that is often associated with a GRB. Astronomers completed a detailed study of data collected a year ago, and definitively showed that GRB are products of high velocity (e.g. light speed) jets moving out asymmetrically from bipolar hypernovae explosions. Meanwhile, another team

of astronomers observed and measured the distance to the farthest cosmic explosion or GRB: 12.8 billion light years. Although they are the brightest events in the Universe, they occur rarely and their remnants fade away in a matter of days. Looking back to the frontiers of space and finding a GRB is an amazing discovery.

A lot of telescope time at Subaru is dedicated to looking at stars to assess their different stages of formation and evolution. Scientists at Subaru have pierced through a dusty stellar nursery of a Class O protostar located 500 light years away and captured the earliest and most detailed view of a collapsing gas cloud turning into a star. Their observation marked the first detection of X-rays and showed that gravity alone is not the only force shaping young stars. Another team of scientists looked at a massive protostar 1,500 light years away and discovered a circumstellar disk in an odd butterfly shape. Their discovery showed that massive stars form the same way lower-mass stars like the Sun. A very young protostar located in the Omega Nebula (M17) was found to be surrounded by an envelope of dust and gas. The relevance of their discovery was significant in understanding the mechanisms of protoplanetary disk formation. Another study located a very old star 4,000 light years away that is the most heavy element-deficient star ever found. The star had the lowest iron abundance ever seen, about  $1/250,000$  of the Sun. The significance of metal-poor stars is that they typically formed when their parent galaxy was young, and the elemental abundance pattern of the star provides an understanding of the nucleosynthesis of first-generation stars, their mass distribution, and their formation processes.

Research into galactic behavior and formation remained a core interest to astronomers at Subaru. A search for transient phenomena in galaxies located 4 billion light years away discovered a rapid increase in visible brightness in their centers. The increase in luminosity occurred over just a few days, lending support to the theory of disks of hot matter rotating close to the speed of light near supermassive black holes. The fact that the visible flares occurred in normal looking galaxies supports the idea that black holes exist in the center of almost all galaxies. Other galactic research involved the well-known and well-studied spiral galaxy NGC 2403. This galaxy has become an important standard galaxy when deciding distances to other galaxies as well as galaxy formation. A detailed image using Suprime-Cam shows evidence of relatively young stars in the halo of the galaxy, hinting at a recent merger with another galaxy.

Two ongoing projects at Subaru include the Subaru Deep Field (SDF) and the Subaru/XMM-Newton Deep Survey Field (SXDS). A few significant events for SDF included the deepest infrared image of the Universe, achieving twice the sensitivity of previous observations, and the discovery of 5,000 young galaxies 12 billion light years away and 800 younger galaxies 12.5 billion light years away. The initial findings showed that small clumps of dark matter may contain multiple young galaxies and that newborn galaxies like to huddle together in a small area.

SXDS studies found that only one billion years after the Big Bang, clusters of galaxies were already forming. This work showed that the largest astronomical objects in the Universe had already begun to form in the earliest stages of the Universe. Additional findings of SXDS included about 17,000 young galaxies 12 billion light years away that showed galaxies are strongly clustered and that young galaxies in the early Universe are nestled in clumps of dark matter. Though still relatively unknown, dark matter is defined as a form of matter of unknown composition whose presence can be inferred from its gravitational effects on visible matter, such as the rotational speeds of galaxies, the orbital velocities of galaxies in clusters, and the gravitational lensing of background objects by galaxy clusters. Through continued research, the correlations between visible and dark matter, especially in the context of galaxy formation, can be identified.