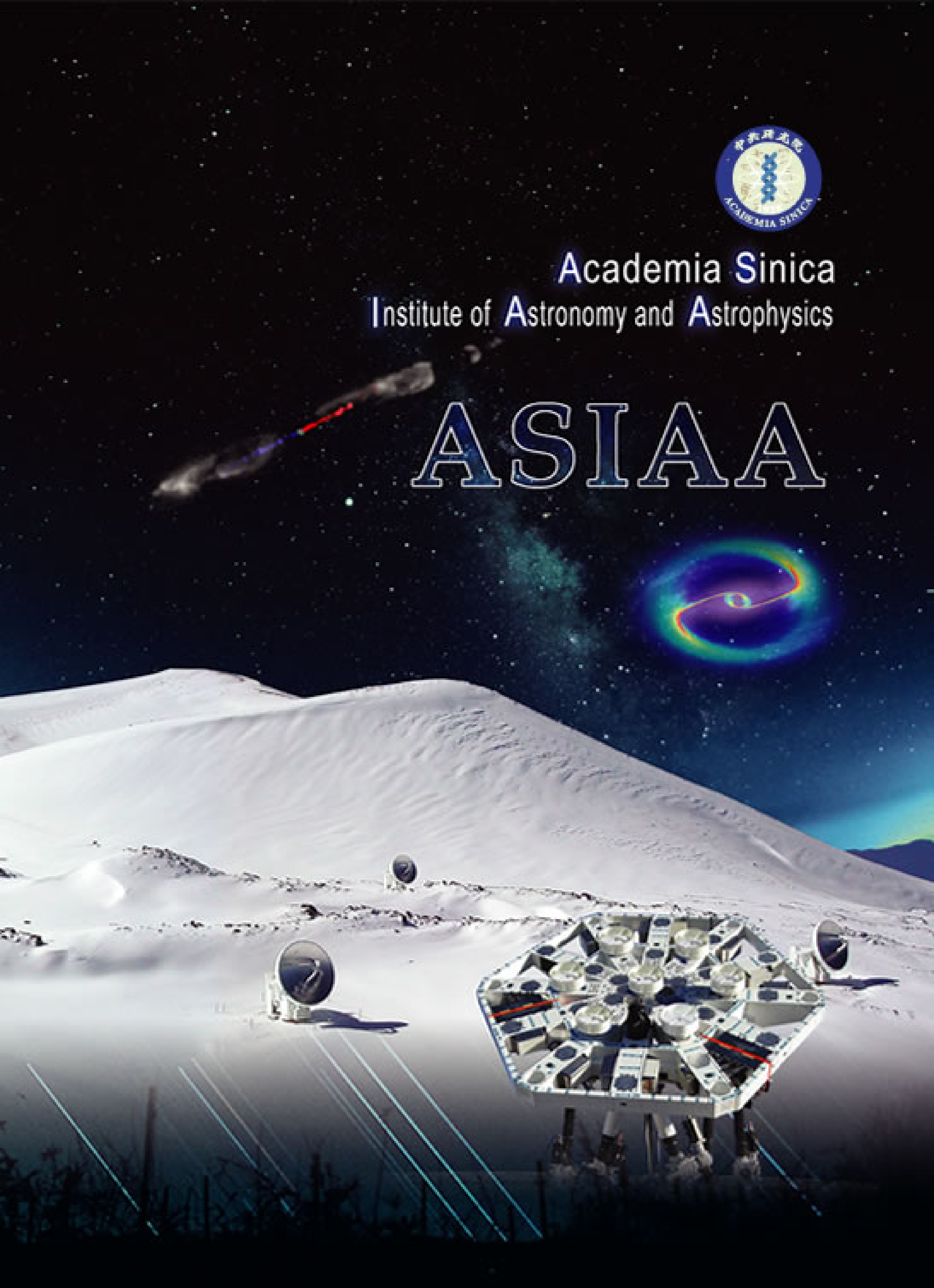

Academia Sinica
Institute of Astronomy and Astrophysics
ASIAA

Dear Colleagues and Friends:

The Preparatory Office of the Academia Sinica Institute of Astronomy and Astrophysics was established with the help of Academician Chia-Chiao Lin and Academy President Ta-You Wu. The rapid growth of our Institute in parallel with the development of astronomy and astrophysics in Taiwan can be traced to the generous support from the Academia Sinica, the Ministry of Education, and the National Science Council in Taiwan.

This pamphlet shows some of the research efforts at our Institute. Our emphasis has been on developing forefront technology and to engage in research on fundamental astrophysical problems. Our staff members pursue a variety of scientific initiatives, ranging from planet formation to black holes to cosmology. We work on observational investigations across all wavelength bands, theoretical studies utilizing both analytical and numerical methods, and instrumentation projects in the radio, optical, and infrared windows. The hard work of our scientists, engineers, students, and administrative staff, are reflected in the fascinating results sampled here. We hope we can communicate to you our excitement in working on the forefront problems in modern astronomy.

The success of our Institute has been guided by a succession of Directors, starting with Typhoon Lee, Chi Yuan, Kwok-Yung Lo, and Sun Kwok. We are grateful for the support of Academy Presidents Yuan-Tseh Lee and Chi-Huey Wong, and the guidance of our Advisory Panel chaired by Frank Shu.

Paul T. P. Ho 11.30.2007

The Submillimeter Array

The Submillimeter Array (SMA) project has been carried out by ASIAA in collaboration with the Smithsonian Astrophysical Observatory (SAO) since 1996. The array was dedicated on Mauna Kea, Hawaii in November 2003 by the previous Academia Sinica President Yuan Tseh Lee and the Smithsonian Institution Secretary Larry Small. It is a radio interferometer operating in the atmospheric windows centered at 230, 345, 400, and 690 GHz. It consists of eight 6 meter radio telescopes, with two of them (including the associated electronics and receiver systems) delivered by ASIAA under close collaborations with university groups and industry in Taiwan. The SMA is the first and currently the only array operating in submillimeter wavelengths. It provides us unique opportunities to observe warm, dense gas and dust at unprecedented high angular resolutions up to 0.1 arc seconds in extent. The research fields include the solar system, star and planet forming regions, evolved stars, and galaxies at nearby and cosmological distances.

As a partner of the SMA project, ASIAA contributes towards the maintenance and operation of the array. ASIAA has a small local staff residing in Hilo, Hawaii. In addition, the scientific and engineering staff visits the site regularly, and conducts remote operation from Taipei.

Figure 1. The Submillimeter Array, an eight-element radio telescope ensemble in the foreground of the figure, is currently one of the most powerful telescopes directly accessible by the astronomers in Taiwan. With its observing frequency of 180 - 690 GHz, the SMA is an unique instrument in the world. The observatories on the ridge, from left to right, are: Subaru Telescope, W. M. Keck Observatory, NASA Infrared Telescope Observatory (IRTF), and Canada-France-Hawaii Telescope (CFHT). (Picture credit: Derek Kubo)

Figure 2. The two telescopes built in Taiwan. (Picture credit: Ming-Tang Chen)

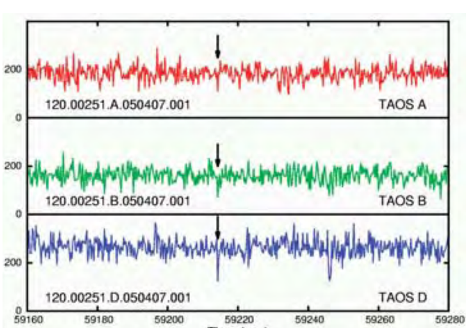
The Taiwan-America Occultation Survey

The Taiwan-America Occultaion Survey (TAOS) project is a collaboration among the ASIAA, the National Central Univeristy, the SAO (Alcock group previously at the Lawrence Livermore National Laboratory and the University of Pennsylvania), and the Yonsei University. TAOS has four 0.5 meter optical telescopes. All of them are now operating on Lu-Lin Mountain with their 2048×2048 CCD cameras tracking thousands of stars per night, searching for occultation by any intervening Trans-Neptunian object (TNO).

TNOs are small objects in our solar system beyond the orbit of Neptune. A study of TNOs may enable a better understanding of the origin of the short-period comets and of the process of planet formation and the early history of our solar system. Since most of them are only a few kilometers in size, a direct observation of reflected sunlight off them is extremely challenging. Currently, occultation is the only way to detect them at such a large distance.

Figure 3. Left: One of the TAOS 0.5 meter telescopes in its enclosure. Right: The four TAOS telescopes on top of Lu-Lin Mountain. Two of them are in the foreground. (Picture credit: S. K. King and H. C. Lin)

Spurious signals due to the atmosphere and equipment can be rejected by coincidence arguments with multiple telescopes running synchronously. Some 100 million stellar photometric measurements have been made. Upgrades to the cameras are being planned to increase the sensitivity of the surveys. The TAOS system is also capable of monitoring several other optical transient phenomena. It has resolved a previously unknown binary in an asteroid occultation event, detected an unexpected stellar flare, and recorded two Gamma ray burst (GRB) afterglows down to 16.5 magnitude in response to the GRB Coordinated Network.



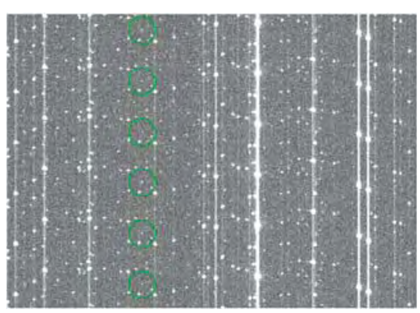


Figure 4. Left: The lightcurves from three telescopes for the possible occultation event detected by TAOS. The arrows show the synchronized drop of the stellar flux. Right: The images show a time sequence of the possible event. The green circle shows the star that had the flux change. (Picture credit: TAOS group)

The Yuan Tseh Lee Array for Microwave Background Anisotropy

The Yuan Tseh Lee Array for Microwave Background Anisotropy (AMiBA) is a forefront instrument for research in cosmology. This project is led, designed, constructed, and operated by ASIAA, with major collaborations with the Physics Department and Electrical Engineering Department of the National Taiwan University (NTU), and the Australia Telescope National Facility (ATNF). Additional contributions are also provided by the Carnegie Mellon University (CMU), the National Radio Astronomy Observatory (NRAO), and the Jet Propulsion Laboratory (JPL). The AMiBA is part of the Cosmology Particle Astrophysics (CosPA) initiative, led by NTU and funded by the Ministry of Education, the National Science Council and the Academia Sinica.

AMiBA is a dual-channel 85-105 GHz interferometer array of up to 19 elements, with full polarization capabilities. It can sample structures greater than 2 arc minutes in size. It targets specifically the distribution of high-redshift clusters of galaxies via the Sunyaev-Zel'dovich Effect (SZE), as a means to probe the primordial and early structure of the universe. AMiBA will also measure the polarization properties of the Cosmic Microwave Background (CMB), which is sensitive to the ionization history of the universe and can be a potential probe for gravity waves. It will improve upon the recent results from Wilkinson Microwave Anisotropy Probe (WMAP) by about a factor of 10 in angular resolution.

AMiBA is sited on Mauna Loa at an elevation of 3,400m in Hawaii. The construction of AMiBA includes a novel hexapod mount, a carbon fiber platform, carbon fiber reflectors, MMIC receivers, a broadband correlator, numerous electronics, a retractable cover, site infrastructures, and software development. The AMiBA has deployed the initial 7-element interferometer in Hawaii. A dedication ceremony was held in October 2006 on Mauna Loa, with previous AS President Y. T. Lee and NTU President S.C. Lee presiding. Science observations have started. An expansion to the 13-element configuration is underway, with deployment and testing in 2008.

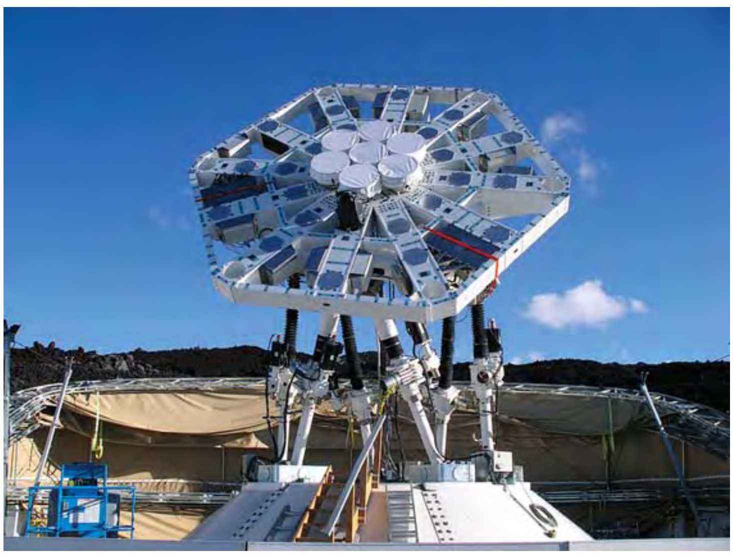


Figure 5. AMiBA on Mauna Loa, Hawaii in September 2006. Seven 60 centimeter antennas, covered with GoreTex sun protection shields, form the most compact configuration on the 6 meter carbon fiber platform. The optical telescope, correlator and associated mechanical and electronic packages can be seen mounted also on the platform. The hexapod jackscrew system can be seen attached to the platform. (Picture credit: Patrick Koch)

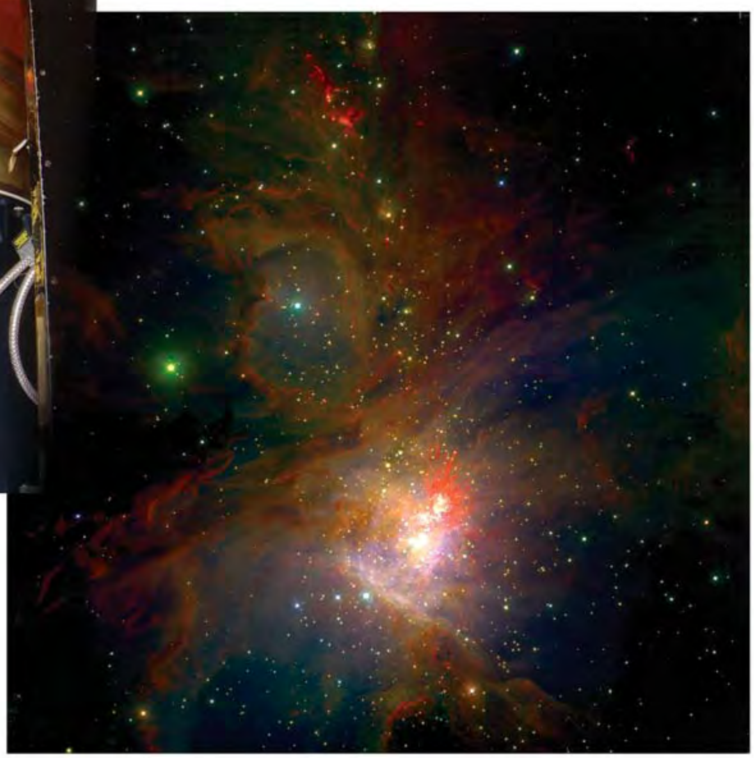
Figure 6. In the dedication ceremony of AMiBA held in Oct 2006, the NTU President S. C. Lee officially announced that the AMiBA is named as "Yuan Tseh Lee Array for Microwave Background Anisotropy" and presented the name plaque of the Array to previous AS President Y. T. Lee. (Picture credit: Fabi Roman)

The Optical and Infrared (OIR) Instrumentation Program

In order to support follow-up observations of high-redshift clusters detected in the AMiBA project and to train the next generation OIR astronomers, ASIAA negotiated for the observing time on the 3.6 meter Canada-France-Hawaii Telescope (CFHT) starting from 2003. This negotiation is a part of the CosPA effort together with the AMiBA development. Technical and financial contribution from ASIAA is in the form of support for the development of the Wide Field Infrared Camera (WIRCam). This camera was already installed and commissioned on CFHT in 2005. It has four 2048×2048 HcCdTe HAWAII-2RG detector arrays, with a 20 arc minute field of view, and a 0.3 arc second pixel scale. It is cooled to liquid nitrogen temperature to suppress the infrared background.

The experience with TAOS and WIRCam development has greatly advanced our capability to build world class optical and infrared instruments. ASIAA is now moving toward to the next instrumentation projects that will further enhance our capability. Participation of the next generation wide field CCD camera -- HSC (Hyper SuprimeCam) -- for the Subaru 8 meter telescope has been discussed with NAOJ, in which ASIAA will be responsible for delivering subsystems for the camera. ASIAA also joins the proposal for the feasibility study of next generation instrument (SPIROU) on CFHT. SPIROU will be an infrared spectropolarimeter that covers the full near infrared wavelengths (0.9~2.4 microns) in a single exposure.

Figure 7. Left: The WIRCam installed on the CFHT. Right: The Orion nebula image taken by WIRCam. (Picture credit: Shiang-Yu Wang and Canada-France-Hawaii Telescope/2006)



Theoretical Institute for Advanced Research in Astrophysics

The Theoretical Institute for Advanced Research in Astrophysics (TIARA) was established in 2004 to provide an integrated world class program of research and education in theoretical astrophysics. The institute is a cooperative effort between the National Science Council and Academia Sinica and aims to coordinate efforts of researchers and the training of future theoretical astrophysicists throughout Taiwan and Asia. It serves as an international center of excellence where forefront research can be intimately integrated into the graduate education at Taiwan's universities and academic institutions. Its primary facilities are located on the campus of National Tsing Hua University with a branch office at the Academia Sinica Institute of Astronomy and Astrophysics in Taipei.

Current affiliated members of TIARA include twenty-three faculty members and postdoctoral research fellows residing in Taiwan and North America, as well as four long term visitors from Asia and Europe. The research activities undertaken by the TIARA scientists span the fields of star formation, galactic dynamics, and high energy astrophysics including compact objects. In order to facilitate continuous intellectual stimulation, TIARA runs an active visitors program and organizes and hosts a vigorous series of topical workshops on especially timely areas. The most recent workshops focus on early solar system mixing and star formation. In addition, TIARA is playing a major role in improving the graduate education of students at universities throughout Asia by holding annual winter schools on special topics in Taiwan. The latest school offered an overview on astrophysical black holes, when approximately 50 students from Taiwan and abroad participated. A team of international experts on the subject was invited to deliver a total of 15 lectures. TIARA is continuing the series with a focus on extra solar plantes in 2008.

Figure 8. TIARA Early Solar System Mixing Workshop held in 2007.

Figure 9. Visitors Danielle Galli from Italy and Susana Lizano from Mexico working with Frank Shu on magnetized gravitational collapse.

Figure 10. TIARA Winter School - Astrophysical Black Holes in 2007.

Atacama Large Millimeter/Submillimeter Array - Taiwan

Since 2005 ASIAA has joined the Atacama Large Millimeter/Submillimeter Array (ALMA) project, the largest ground-based astronomical project ever carried out. The array is currently under construction in the Chajnantor area in the Atacama desert in northern Chile. ALMA will cover a wavelength range from 0.3 to 9 millimeters with an angular resolution of up to 4 milli-arc seconds, giving images 10 times sharper than the Hubble Space Telescope.

The ALMA project has three major international partners: North America, Europe, and Japan. The North American and European partners are responsible for the construction of the 12 meter Array (ALMA-baseline project), while Japan is responsible for the construction of the Atacama Compact Array (ACA; ALMA-Japan project). ASIAA has been participating in the ALMA Project through ALMA-Japan. Additional cooperation with ALMA-NA (North America) is under negotiation. ALMA will be completed in 2012, and its expected lifetime is at least 50 years.

ALMA will be enormously sensitive, and more than 10,000 times faster than any existing instrument at millimeter and submillimeter bands. The extremely high sensitivity of ALMA will allow us to study a broad range of exciting science such as weather patterns on the solar system planets, the formation of planets and stars in our galaxy, the gas motions within active galactic nuclei, and the formation of the earliest galaxies. For example, imaging protoplanetary disks around young Sun-like stars with resolution of a few astronomical units will enable us to detect the tidal gaps created by planets undergoing formation in the disks.

In addition to preparing for scientific projects for ALMA, ASIAA will also contribute to the construction of the array and associated engineering projects. For example, under collaboration with Chung-shan Institute of Science and Technology Aeronautical Systems Research Division (ASRD) in Taiwan, ASIAA has been establishing the East Asian Front-End Integration Center (EA-FEIC), where all the front-end subsystems for ACA will be assembled and evaluated, and then will be shipped to Chile.

Figure 11. The first three 12-meter antennas of ALMA-Japan constructed at the ALMA Operations Support Facility in Chile (picture credit: NAOJ).

Solar System

Comets are dirty snowballs that contain lots of dusts. They were believed to have formed in the outer solar system about 4.5 billion years ago, carrying important information about the early days of the solar system. The Stardust spacecraft of NASA, after seven years of journey, flew by Comet/Wild-2 and caught comet dusts near the nucleus for the very first time. The comet samples were returned to Earth on January 15, 2006.

The most striking discovery from the comet dusts is small particles that have formed under very high temperature (~1700˚C and possibly higher), similar to the Calcium-Aluminum Inclusions (CAI) found in carbonaceous meteorites, which were not local products made at the extreme cold (lower than −200˚C) of the outer solar system. These particles should have been melted and solidified in the central high-temperature region in the innermost proto-solar system (closer by 10 times from the distance of Mercury) and later transported to the outermost reaches of the solar nebula by a powerful bipolar outflow. This suggests that in the early solar system, large-scale and large-distance mixing and interactions for the matter between the inner and outer solar system existed, as predicted in our X-wind model of chondritic meteorites more than 10 years ago (Shu, Shang, & Lee, 1996, Science 271, pp1545-1552).

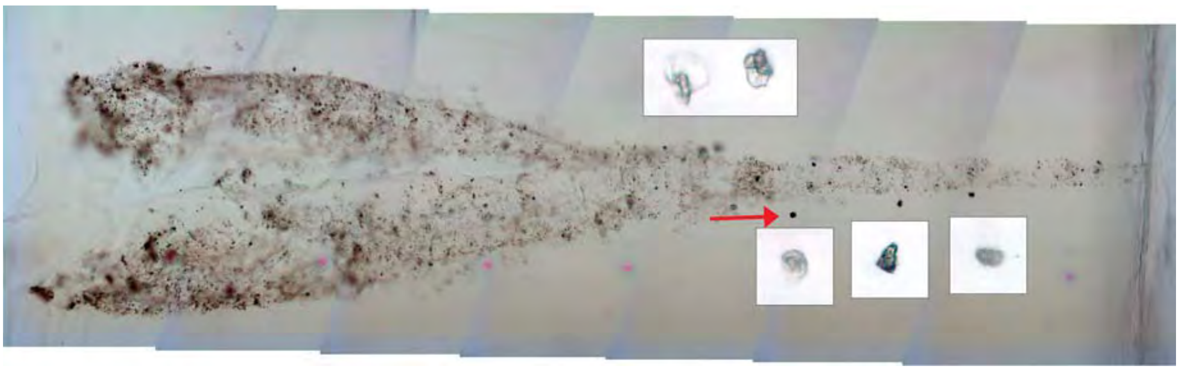


Figure 12. Comet samples collected by NASA Stardust spacecraft: small (<0.01 centimeters) particles entered from left, along a deceleration trajectory, and terminate on the right, making many fragments (small inserted pictures). The red arrow labels one particle that is like the CAI, believed to have formed under high temperature environment in the inner solar system. (Credit: NASA Johnson Space Center.)

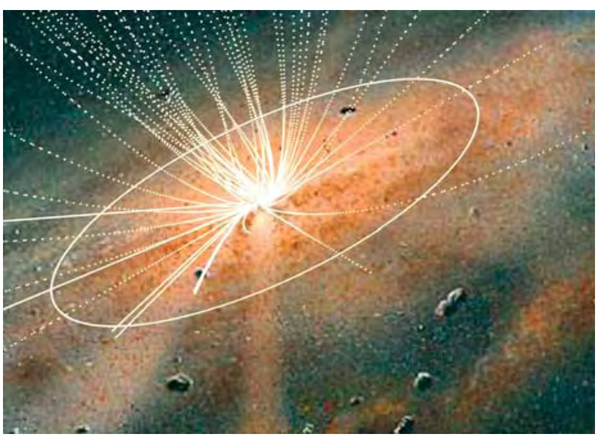


Figure 13. Shu, Shang, and Lee applied the X-Wind theory to the formation of high-temperature material in the early solar system (such as chondrules and CAIs from chondritic meteorites). The circle labels the very young solar system at 3AU, in which matter falls through, attracted by gravity, and accretes onto the forming young Sun. A fraction of the matter will turn into the X-Wind, launched along the dotted lines near the Sun. CAI particles of various sizes, whose trajectories are labelled by the solid lines, melted and solidified under high temperature, are thrown out by gas in the X-Wind, then detached and dropped like a fiery rain over the whole solar nebula. (Picture Credit: trajectory: Hsien Shang, background image: William K. Hartmann).

Low-mass Stars

The stars that we study here are lighter than our Sun. We discovered a wide pair of low-mass dwarf stars (Phan-Bao et al. 2007). Follow-up spectroscopic observations confirmed a spectral type of M0 (0.5 solar mass) for the primary (hereafter ASIAAa) and L0 (0.1 solar mass) for the secondary (hereafter ASIAAb). The projected separation between ASIAAa and ASIAAb is large, about 400 astronomical units (AU). The presence of Balmer line emission in ASIAAa indicates that the star is magnetically active. The wide binary provides us opportunities to test atmospheric theoretical models since the components are expected to have the same age and metallicity.

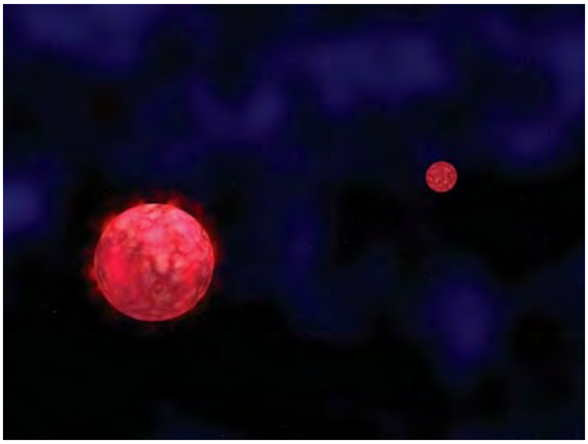


Figure 14. The wide binary: ASIAAa and ASIAAb (Credit ASIAA/Artwork by Change Tsai).

The ejection models of brown dwarf (very low mass, below 0.08 solar mass) formation predict that the binary brown dwarf systems that do exist must be close (separations $\leqq$ 10 AU). We (Phan-Bao et al. 2005) discovered a wide very low-mass binary system, LP 714-37AB, consisting of two very low-mass ($\leqq$ 0.3 solar mass) dwarf stars with a projected separation of 33 AU (Figure 15, left panel). The existence of wide binaries is therefore at first sight inconsistent with the ejection model, suggesting that at least some very low-mass stars and brown dwarfs form through another process. A caveat, however, is that some apparent binaries might be unresolved triple or higher order multiple systems, whose additional components could boost the binding energy of the systems enough to allow them to survive ejection. Our follow-up adaptive optics observations of one such system, LP 714-37AB, did resolve the secondary into a tighter pair (Figure 15, right panel, Phan-Bao et al. 2006). The system LP 714-37 therefore demonstrates that some wide apparent very low-mass binaries are actually higher order multiple systems and no longer contradict the ejection scenario for brown dwarf formation.

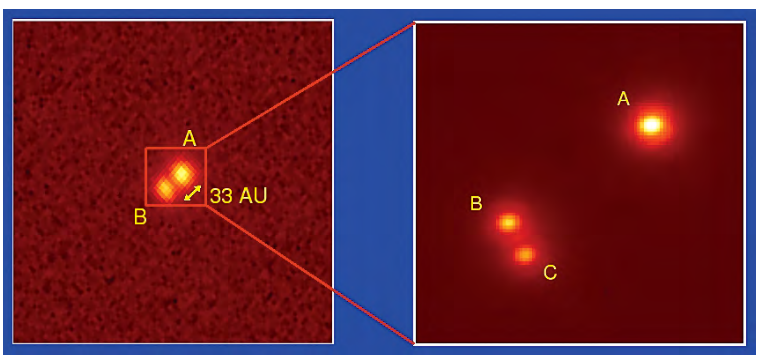
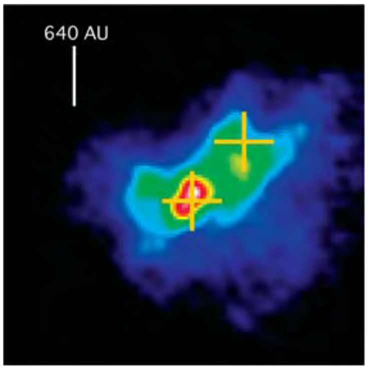


Figure 15. LP 714-37: A wide pair of ultracool dwarfs actually is a triple.

Star Formation

Stars including our Sun are basic building blocks of the Universe and it is important to understand where and how they come to be. It is believed that stars are formed inside dusty cocoons called "molecular cloud cores" by means of gravitational collapse. The details of the process, however, are complicated by the presence of magnetic field and angular momentum. We aim to advance our understanding of star formation by detailed studies toward nearby star-forming regions in our Galaxy, in observation and theory.

Dense condensations called "protostars" will first form in the beginning and then grow into stars in tens of million years as gas and dust continue to fall onto them. Interestingly, gas and dust are also found to be ejected rapidly from the protostars, forming bipolar jets emanating from them. The jets are now known to be the keys to remove excess angular momenta from the star-forming regions.



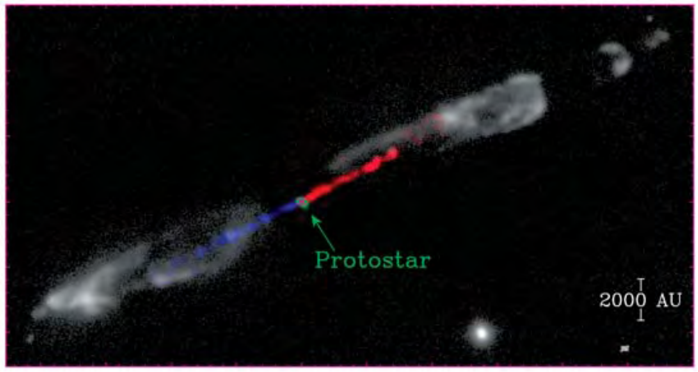
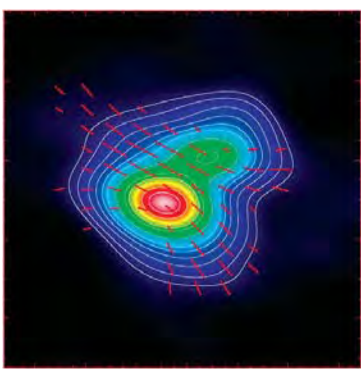


Figure 16. Left: Molecular gas in the star-forming region IRAS16293-2422 observed with the SMA and James Clerk Maxwell Telescope (JCMT). The gas is falling toward the protostars (cross marks) due to gravitational collapse (Takakuwa et al. 2007). Right: The bipolar (red for receding and blue for approaching sides) jet in the star-forming region HH 211 observed with the SMA (Lee et al. 2007). Gray image shows the shock emission produced by the jet (Hirano et al. 2006).

As a strong evidence of gravitational collapse, the magnetic fields in the molecular cloud cores are found forming hour-glass shapes around the protostars. In the close proximity of the protostars, magnetic fields are also believed to play a crucial role in channeling material onto the protostars and launching the jets. The X-wind model that accounts for such processes has been studied extensively in ASIAA. In this model, a magnetized accretion disk is formed around the protostar, from which part of the material is accreted by the protostar and part is ejected away. A numerical simulation with the model also produces a jet as seen in the observations (Shang et al. 2006).



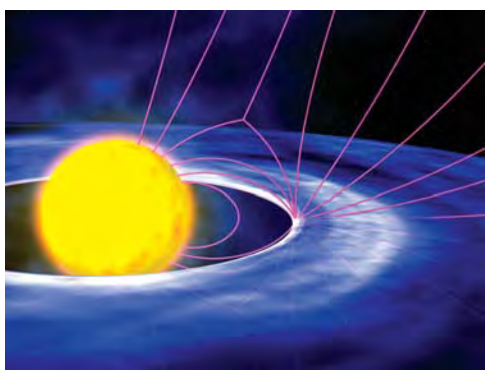


Figure 18. Left: The hour-glass shaped magnetic field (red dashed lines) seen by the SMA in the star-forming region NGC1333 IRAS4A (Girart, Rao, & Marrone 2006). Right: A schematic drawing of the X-wind model in the close proximity of the protostar (Picture credit by Mike Cai).

At the end of star formation, protoplanetary disks are seen around newly-born stars. They are the most promising sites for planet formation. The protoplanetary disk around the bright star, AB Aurigae, is promising because of its spiral arm structures. The rotation of the disk is found to depart noticeably from Keplerian motion, suggesting that there may indeed be a giant (Jupiter-sized) planet forming inside the disk responsible for the perturbation in morphology and kinematics, as seen in our simulation.

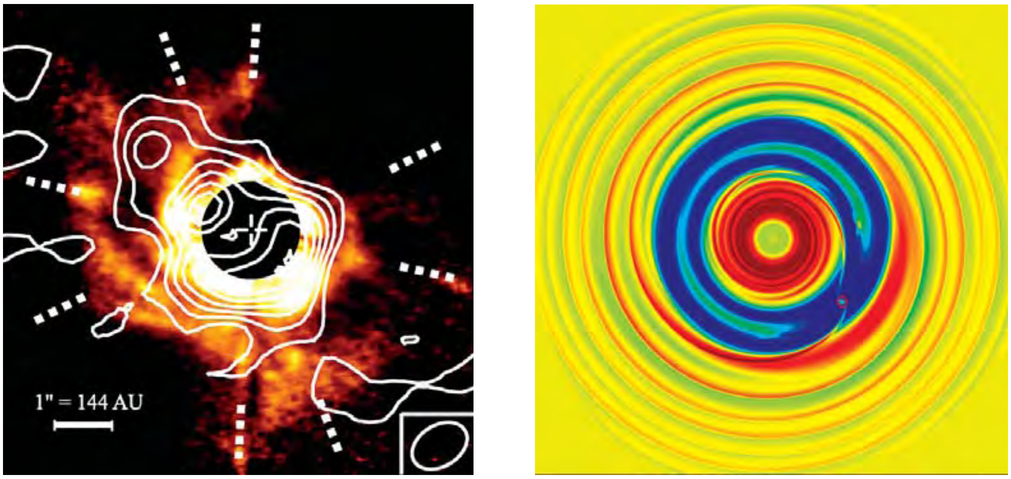
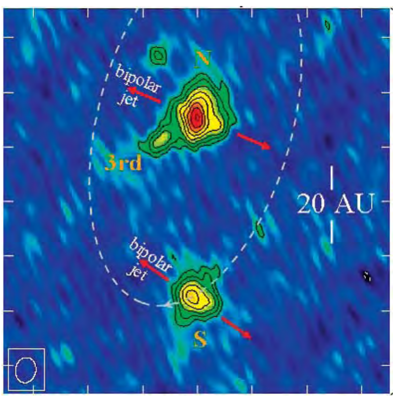


Figure 19. Left: Dust emission (contours) observed with the SMA and spiral arm structures (image) observed with the Subaru telescope in the protoplanetary disk of AB Aurigae (Lin et al. 2006). Right: Numerical simulation of a planet interacting with a protoplanetary disk (Zhang, Yuan, Lin, & Yen 2007, submitted).



Currently, it is still unclear why multiple protostars are often seen within a single protostellar system, for example, three protostars are seen in the protostellar system L1551 IRS 5. The disks associated with two of them are found to be aligned parallel to each other, as well as to their parent disk-like condensation of gas and dust. Our observation supports the popular yet hitherto unproven idea that multiple protostars form via fragmentation in the central region of their parent condensation.

Figure 20. The protosteller system L1551 IRS5 observed with the VLA. Red arrows denote bipolar jets. (Lim and Takakuwa 2006).

How high-mass stars (more than 8 times the mass of our Sun) form is still currently under debate. Our observation toward the high-mass protostar IRAS 20126+4104 clearly shows a bipolar outflow and a compact rotating disk surrounding the protostar. Similar to that seen toward the low-mass protostars, our observations suggest that the high-mass stars form the same way as the low-mass stars.

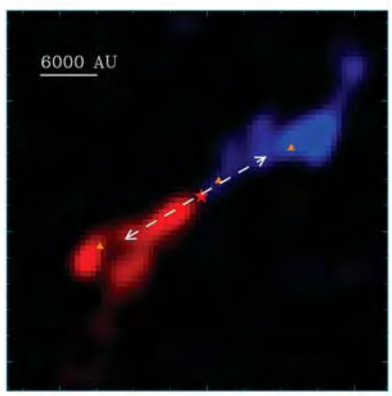


Figure 21. Bipolar outflow from the high-mass protostar IRAS 20126+4104 observed with the SMA. Red for receding and blue for approaching part of the outflow. (Su et al. 2007)

Evolved Stars

Most stars including our Sun will end their lives rapidly, evolving first into red gaint stars and then white dwarfs. Red giant stars represent a short but very important phase, during which the stars contribute significantly to the enrichment of the interstellar medium by ejecting most of their mass in the form of a slow and dusty wind. The study of circumstellar envelopes created by the mass ejection process has provided vital information for our understanding of the red giant phase and helped to elucidate different physical and chemical processes at work in the envelopes.

We have recently carried out a large and systematic spectral line survey toward a number of massive circumstellar envelopes using the radio telescope of the Arizona Radio Observatory. For example, in the envelope of the carbon star CW Leo, lines are seen mainly from carbon chain molecules such as cyanoacetylene HC_3N, butadiynyl radical C_4H, and silicon dicarbide SiC_2. We will study the chemical processes leading to the formation of such complex molecules.

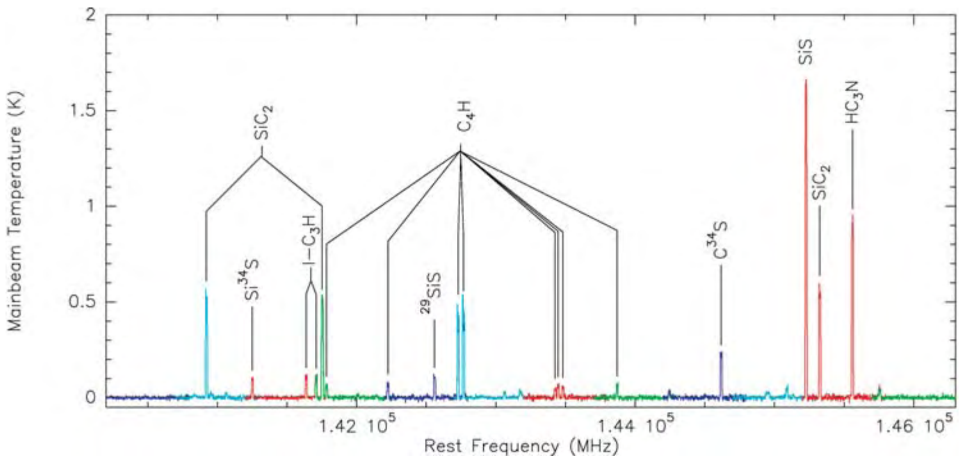


Figure 22. Spectrum toward the carbon star CW Leo, taken with the Arizona Radio Observatory 12 meter telescope (He et al. 2007).

The peculiar red supergiant VY Canis Majoris is interesting because of its highly complex circumstellar environment. With a detailed modeling, the molecular gas is found to possess two distinct kinematical components: a fast-moving bipolar outflow and a slowly-expanding spherical envelope (Muller et al. 2007).

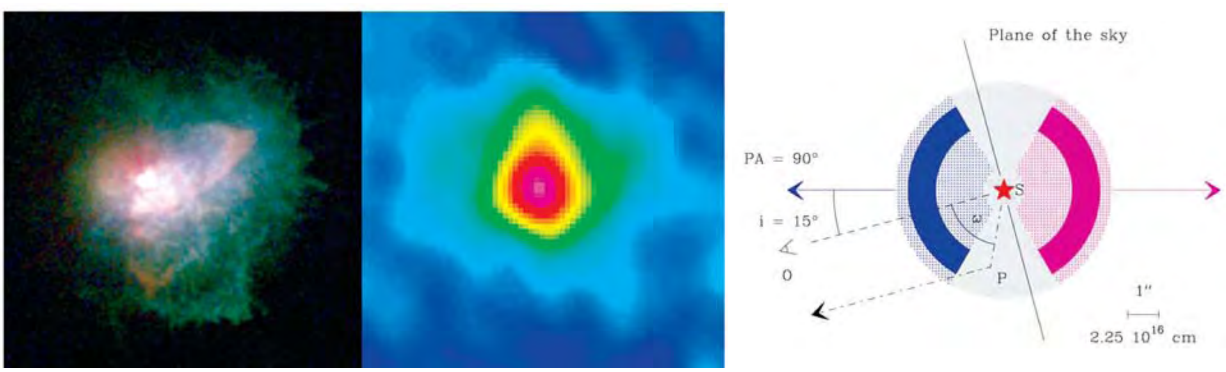


Figure 23. Left: HST optical image of VY Canis Majoris (Smith et al. 2001). Middle: Molecular gas around VY Canis Majoris observed with the SMA. Right: Structure of the gas with fast-moving bipolar outflow shown in red and blue colors. Red for receding and blue for approaching part of the outflow. (picture credit: Muller et al. 2007).

High Energy Astrophysics

Astronomical phenomena involving compact stellar objects are particularly fascinating since they can emit the greatest power in the Universe. Objects such as neutron stars and black holes are intrinsically of great interest as they are cosmic laboratories where their extreme conditions cannot be replicated terrestrially. As such they are critical for probing the state of matter at very high density and for probing the curvature of space time surrounding them.

We have interests in the origin and evolution of these stellar objects as well as the nature of the radiation they emit. Since these objects are so compact, they emit significant radiation at very high energies. For example, the rapidly rotating highly magnetized neutron stars, known as pulsars, are important sources of high energy gamma rays. Observations of such pulsars are used to provide information on the processes of particle acceleration under extreme conditions. An example of the particle-acceleration zone and the predicted gamma-ray emission properties are shown in figure 24 .

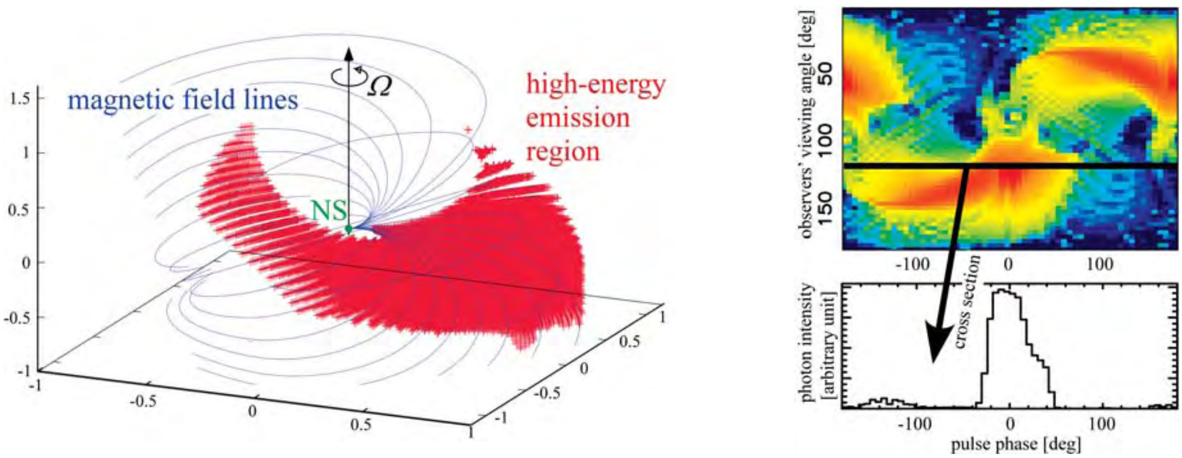


Figure 24. (left) Distribution of the emission region (red crosses) in a pulsar magnetosphere. The entire scale is a few thousand km. (right) Top: computed photon intensity on the pulse phase vs. observers' viewing angle plane, where the red region indicates the largest intensity. Bottom: predicted pulse profile during one spin period of the neutron star. (picture credit: Kouichi Hirotani)

Among the brightest stellar X-ray sources in our Galaxy as well as in external galaxies are binary star systems in which a compact black hole or neutron star member accretes matter from a stellar companion. In contrast to the pulsars, where energy is derived from the rotation of the neutron star, these sources derive their energy from the accretion of matter to their surface. Many such systems undergo transient outbursting phenomena allowing astronomers to observe a source over a wide range of conditions. Such observations have given astronomers a mental picture of the nature of the emission regions surrounding a black hole. A picture of the region of emission from a disk surrounding a black hole is illustrated in the following figure.

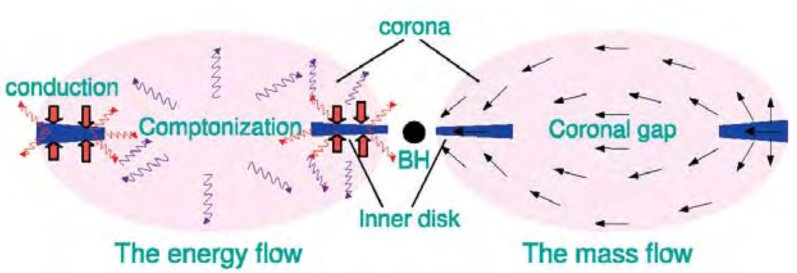


Figure 25. A schematic illustration of the mass and energy flow in a disk surrounding a black hole in a X-ray transient system in its quiescent state (see Liu, Taam, Meyer-Hofmeister, and Meyer 2007).

Extragalactic Studies

Active Galactic Nucleus (AGN) is believed to be the luminous visible evidence for the vigorous accretion of gas onto a super-massive black hole at the center of a galaxy. One important research activity is the study of molecular gas around AGNs. The general models suggest that molecular gas is rotating around AGN as a disk or a torus, but is this simple view true? Our high spatial resolution carbon monoxide (CO) gas observations toward nearby Seyfert galaxies with the SMA and other interferometers show very complicated molecular gas properties, and the gas near the AGN seems to be largely affected by the AGN activity.

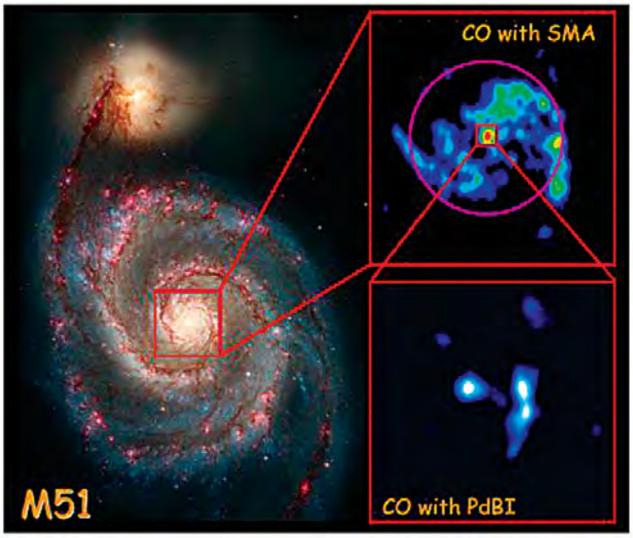


Figure 26. Our CO imaging studies of the nearby Seyfert galaxy M51 with the SMA and Plateau de Bure Interferometer (PdBI) show that the molecular gas distribution around the Seyfert nucleus is very complicated and show no clear evidence of a disk- or torus-like feature. [Left image: the HST Hubble Heritage (NASA, ESA, S. Beckwith and the Hubble Heritage Team). Bottom-right image: Matsushita, S., Muller, S., & Lim, J., 2007, A&A, 468, L49]

We are also studying the relation between molecular gas and star formation in galaxies. Stars are formed from molecular gas and in return the molecular gas is affected by radiation from stars. The observations of the distribution and properties for various molecular species therefore reveal the star formation activity. Our molecular gas observations toward a very active star-forming (starburst) galaxy show more active star formation than our Galaxy.

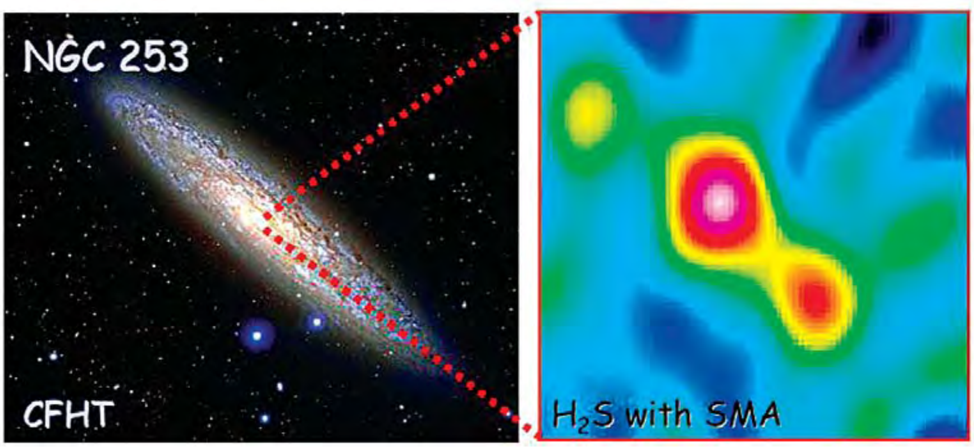


Figure 27. The H_2S image of the nuclear region of the nearby starburst galaxy NGC 253, as observed with the SMA. H_2S gas is believed to trace the on-going star formation activity. A rough scaling indicates that there might be thousands of star-forming cores each in the two brightest peaks [Left image: CFHT. Right image: Minh Y.C., Muller S., Liu S.-Y., & Yoon T.S., 2007, ApJ, 661, L135]

Cosmology

Cosmology is a study of the nature, origin, and evolution of the Universe. Theoretical models are constructed to describe our Universe and to provide us with specific predictions of physical phenomena, such as gravitational bending of light rays (gravitational lensing) and large-scale clustering of galaxies. Such models can be tested by comparing the predictions with astronomical observations.

A cosmology group has been assembled in support of the AMiBA project. The first AMiBA detection of the thermal Sunyaev-Zel'dovich (SZ) effect has been obtained towards the nearby massive cluster of galaxies, A2142. The thermal SZ effect is a direct probe of the thermal energy (pressure) content of the hot gas in clusters, and is a powerful tool for testing and obtaining a better understanding of cluster physics.

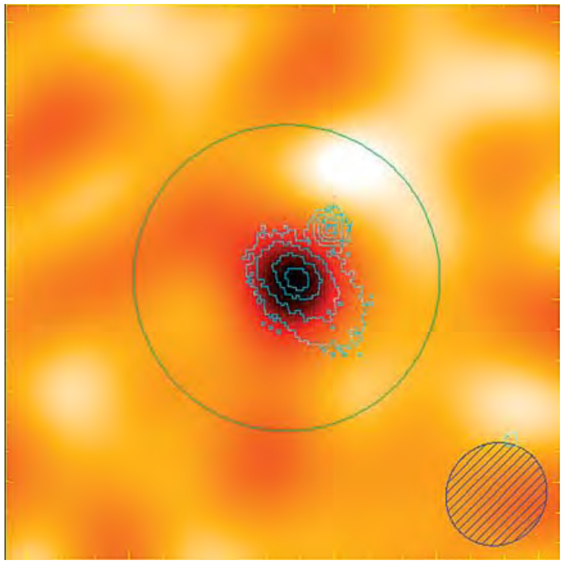


Figure 28. Abell 2142 is a nearby massive merging cluster of galaxies. The cluster is seen as a cold spot by the AMiBA. It is one of the brightest SZ sources on the sky due to its proximity and large mass (picture credit: Kyle Lin and AMiBA group)

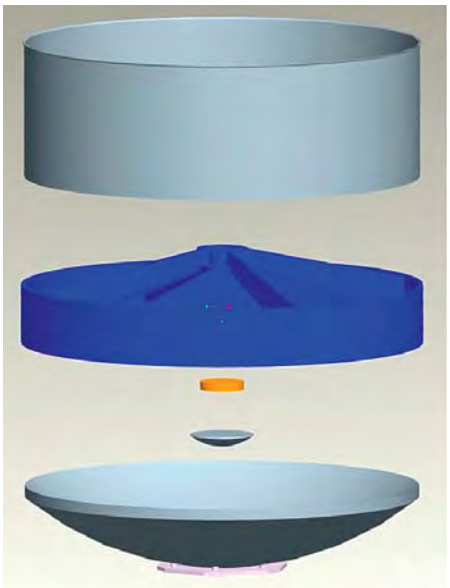
The cosmology group also makes use of other instruments such as the Subaru and the CFHT to pursue optical studies of distant clusters and large-scale structures of the Universe. Galaxy interactions and mergers play an important role in the evolution of galaxies. The merger history is directly related to how galaxies form and how the cosmic structures of the Universe, such as groups and clusters of galaxies, come to be. Therefore, by measuring the frequency of galaxy mergers and by studying the properties of interacting galaxies, we can place constraints on theoretical models of galaxy formation, which could further improve our understanding of cosmic structure formation in the Universe. We will use imaging data from the DEEP2 Redshift Survey and the Red-Sequence Cluster Survey to pin down the evolution of merger rates as a function of cosmic time, and to investigate how the present-day galaxies have evolved through mergers in the past 8 Gyr.

Figure 29: An HST image of one of the most famous interacting systems, the Antennae galaxies. Regions in pink indicate that a number of stars are being born triggered by the collision of two gas-rich galaxies [Picture Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration. Acknowledgement: B. Whitmore (Space Telescope Science Institute) and James Long (ESA/Hubble)].

Submillimeter Receiver Laboratory

The instrumentation research in ASIAA started with the establishment of the receiver laboratory in 1995, for the construction, testing, and integration of the SMA receiver. Since then, we have developed the expertise in the instrumentation of sensitive radio-wave receivers, which involves projects in the area of cryogenics, quasi-optics, microwave and millimeter-wave devices, analog and digital electronics, precision mechanical design and machining. Our core technologies focus on three important topics -- The superconductor-insulator-superconductor (SIS) junction design and fabrication, the development of monolithic microwave integrated circuit (MMIC), and the facilitation of complex receiver system design and integration.

In collaboration with various laboratories and experts in the world, we took on the technical driving role in the AMiBA project. In November 2002, the ASIAA receiver team has successfully established the AMiBA prototype receiver system on the site of Mauna Loa Observatory. In 2005, the telescope site infrastructure was completed, and the telescope mount was erected on Mauna Loa. The AMiBA 7-element was officially dedicated in October 2006. An expansion to the 13-element AMiBA is underway.



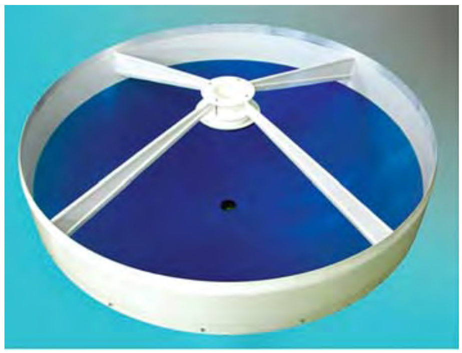


Figure 30. 1.2 meter Cassegrain antenna for AMiBA. The antenna structure is made of carbon fiber for its light weight. The reflective surfaces are aluminized plating with titanium-oxide protecting layer. In total, thirteen antennas will be made for the AMiBA project by CoTech Inc., in Taichung, Taiwan. (Provided by Ted Huang.)

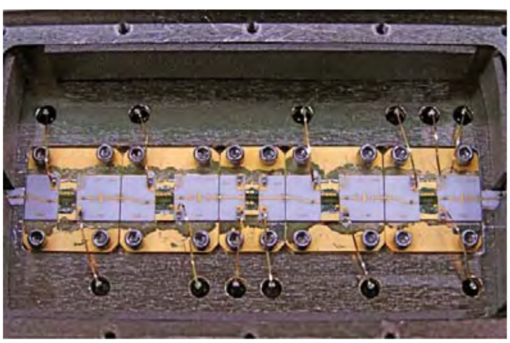


Figure 31. A prototyping System-on-Block for AMiBA intermediate frequency (IF). This is a newly developed methodology to miniaturize a fairly complex and bulky module into a block fitted in one's palm. Various MMIC devices with different functionality are pre-assembled with their associated circuitries (white substrates) on the gold-plated substrates. The substrates are then precisely aligned and integrated with the rest of the block to form a complex module. This is collaborative project between ASIAA and the Electrical Engineering Department of the National Taiwan University for replacement of the AMiBA IF system. (Provided by C. C. Han)

International collaboration is a key to today's ever-increasing complexity of instrumentation systems. We are constantly working with our colleagues from the National Radio Astronomy Observatory (NRAO, USA), the Australia Telescope National Facility (ATNF), the National Astronomical Observatory of Japan (NAOJ), the Purple Mountain Observatory of China (PMO), the Smithsonian Astrophysical Observatory (SAO), and experts in various universities in the US. Nationwide, we have teamed up with our colleagues in the National Taiwan University (NTU), National Tsing-Hua University (NTHU), the Chung-Shan Institute of Science and Technology, and experts in several local industries.

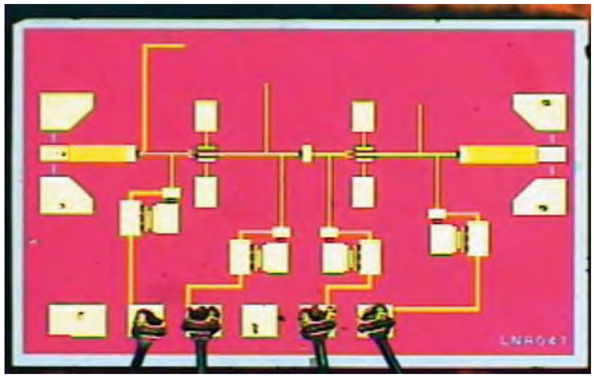


Figure 32. A prototype LNA chip covering 31 to 45 GHz. This chip comes from a developmental wafer run in the WIN semiconductors Inc., Taiwan, using a 0.15-micron mHEMT process based on their more mature pHEMT technologies. The measured noise figure of the chip ranges from 4 to 5 dB at room temperature. Measurements at low temperature are in preparation. (Provided by C. C. Chiong)

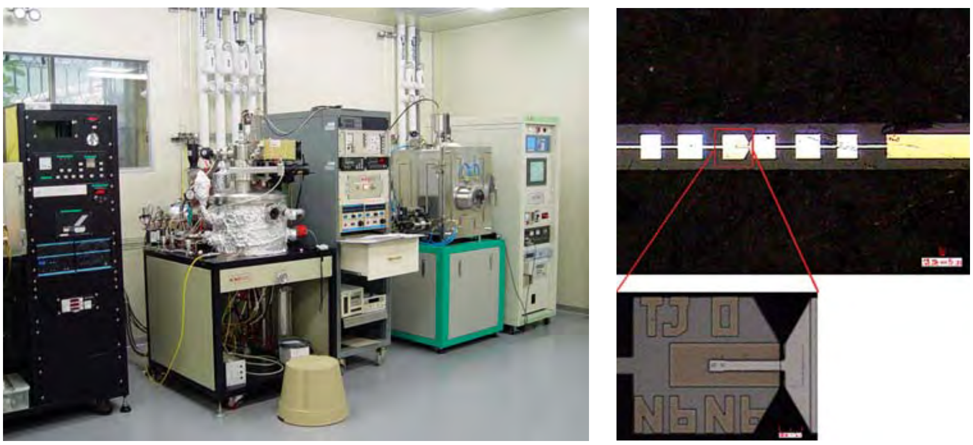


Figure 33. Left: The new clean room for mixer fabrication located at NTHU. Right: A niobium SIS mixer developed in ASIAA for SMA 850 GHz prototype and for ALMA band-10 receivers. The SIS fabrication facility in ASIAA securely supply the most important components for the SMA project. It also leads to technology development into new area of instrumentation, such as far-infrared detectors and SQUID. This is a collaborative effort between ASIAA and National Tsing Hua University, Taiwan. Internationally, we also collaborate with experts from the Purple Mountain Observatory in China, the National Astronomical Observatory of Japan, and the Smithsonian Astrophysical Observatory. (Picture credit: Ming-Jye Wang)

The ASIAA receiver group is constantly seeking opportunities to undertake challenging projects. Its role in ASIAA is not only to support the instrumentation effort, but also to stimulate thinking in new research directions, and to motivate our scientific members in ASIAA for new initiatives into unexplored regimes of the Universe. As a fairly young technical team, we are on fast learning curves of major technologies.

Optical/infrared Instrumentation Development

Building upon the experience in developing WIRCam for CFHT, the IAA has undertaken small local projects to enhance collaboration and relationship with the local industry in support of future large international collaborations. Two major projects are the InGaAs array development in cooperation with Chunghwa Telecom Corporation and the InAs quantum dots (QDs) IR detector development with National Chiao Tung University.

Large and high quality imaging arrays are the hearts of modern infrared astronomical instruments. A collaborative project was proposed by the Advanced Technology Research Laboratory of Chunghwa Telecom (ATR Lab.) to develop cheap alternative infrared arrays for astronomical applications. We worked with the ATR Lab to test the cryogenic characteristics of the InGaAs arrays. The ATR Lab provides 320×256 and 640×512 arrays with a cutoff wavelength around 1.7 microns for the project. The goal of current testing is to confirm the performance and packaging of the array under cryogenic temperatures. Further improvements of the arrays will be pursued after the performance of the arrays is well characterized.

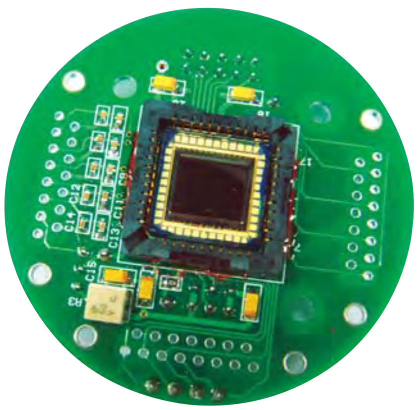
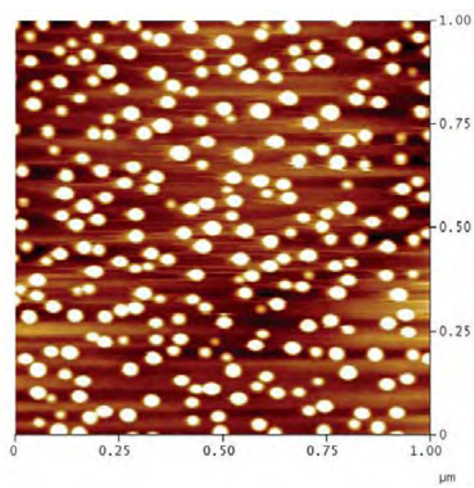


Figure 34. The interface board and the 320×256 InGaAs array for the characterization system.

Infrared detectors utilizing semiconductor QDs have been predicted to have the advantage of low cost and high operating temperature. With the self-assembled QDs, many efforts have been concentrated to improve the performance of quantum dot infrared photodetectors (QDIPs). However, by considering the repulsive potential generated by the charge inside the QDs, the capture probability, and thus the current gain, is shown to be greatly affected. With this idea, the charge of the carrier inside the QD can be calculated from the current gain. More work on the fabrication of such QDs has been undertaken. The manufacturing of an IR array with QDIPs is also planned.



In addition, an infrared camera project for the local Lulin 1 meter telescope has been initiated. With a HAWAII-1 array from CFHT, we plan to build the first IR astronomical camera in Taiwan as an exercise after the training of WIRCam.

Outreach Activities

ASIAA hosts outreach activities to improve the astronomical education of the public and to inform the general public of its achievements. These activities include the AS regular open house, a web server dedicated for posting major ASIAA achievements and worldwide astronomical news in Chinese, visits by high school students, astronomical talks for the public, and the “2007 Go to Hawaii” outreach activity.

AS open house activity

AS holds an open house every year, with the mission to explain to the public the exciting research activities conducted at the Academy. The event in 2007 involved about 25 ASIAA members including research fellows, research assistants, and administrative staff. To pique curiosity and inform the public, two popular talks titled “Making planets and the possibility of extraterrestrial life” and “The Three Hairs of Black holes” were presented to the audience who are mostly non-scientists. We also displayed several posters, exhibits, TV programs and remotely controlled our telescopes in Hawaii and on the summit of Lulin mountain. The audience received a first hand experience in astronomical research. To introduce the culture of Hawaii where the IAA radio telescopes are located, we invited the Hula Angel club to perform the traditional Hula dance.

Figure 36. A Hula Dance by Hula Angle club.

Figure 37. ASIAA research assistant explaining how astronomers observe stars by an hand-made optical telescope provided by Taipei Astronomical Museum.

ASWEB web server (http://asweb.asiaa.sinica.edu.tw)

Since October 2003, we have been maintaining a web site written in Chinese dedicated to the newest astronomical discoveries. The web server also provides a video-on-demand function to allow users to select and watch astronomical talks and lectures.

Figure 38. A snapshot of the ASWEB

Cooperation with the Taipei Astronomical Museum (TAM)

Encouraged by the success we enjoyed on open house days, we have developed a series of popular science talks for the general audience at the Taipei Astronomical Museum starting from May 2006. These talks are aimed at senior high school teachers and students in astronomical clubs. The audience can discuss the presentation with the speaker face-to-face after a talk. All talk information and materials are collected and displayed on the web (http://asweb.asiaa.sinica.edu.tw).

Figure 39. A popular science talk at TAM.

Video production with the Public Television Service Foundation

Since 2005, ASIAA and the Public Television Service Foundation have collaborated in producing three astronomical TV programs. They are “Explore the unknown-SMA”, “Galaxies waving their spiral arms” and “Comets: The ancient fossils in the solar system”. All these TV programs serve to highlight ASIAA's achievements as well as promote its visibility in the community.

Figure 40. Consisting of eight 6 meter antennas, the SMA can simulate a 508 meter single dish telescope. The above is an artist's conception of such a single dish telescope, which occupies an area equivalent to nine football fields. (Picture credit: Public Television Service Foundation)

2007 Go to Hawaii

Astronomy is in its golden age. Taiwan is engaged in the front line of astronomical research. To share our discoveries and our work with the young people of Taiwan, ASIAA invited two senior high school teachers to visit SMA and AMiBA in Hawaii July 2007. ASIAA strives to impress the young people that the whole universe is in front of them. Formosa TV Station recorded this visit and made a 15 minute TV program.

Figure 41. Top: Students in Academia Sinica talking with their teachers in SMA control room by video conference. Bottom: Two senior high school teachers and two journalists with our colleagues, taken in Hawaii.

Education

One of the central missions of ASIAA is to help educate and train the next generation of Taiwanese astronomers. We work in close coordination with universities to encourage and support their students to engage in front-line research in astronomy. While ASIAA does not provide its own degree program, many graduate students are working for their degrees under joint supervision of ASIAA faculty members and professors in their own universities. Many of the research activities at ASIAA are conducted in collaboration with universities in Taiwan and abroad. Joint research projects, seminars and conferences, visitor programs, and adjunct appointments, are part of the ASIAA effort to cooperate with universities. ASIAA also organized an Interferometer School in 2006, specifically for students who are interested in using radio interferometers such as SMA and ALMA for their research.

Summer Student Program

For undergraduate students interested in astronomy, ASIAA offers a Summer Student Program to introduce modern astronomical research experiences. A selected student typically works on a specific topic under the supervision of our research staff for two months. One of the major purposes of this program is to provide the opportunity for students to learn, at first hand, the various aspects of an advanced astronomical research program. A series of lectures are also offered to broaden the exposure of the students to different research topics. Many summer students continue their research after the summer program. Website: http://www.asiaa.sinica.edu.tw/Education/ SummerStudents/

Figure 42. Left: The supervisors having lunch with their summer students on the first day of the 2007 summer program. Right: The 2007 summer student s attending a summer lecture.

Open Opportunities for Undergraduate/Graduate Student

ASIAA provides a rich opportunity for students at all levels to carry out frontier research under the supervision of Institute scientists. Talented undergraduate students can find part-time employment to conduct research with a selected mentor. This provides a deeper and richer research experience which is important preparation for future graduate studies. Talented Bachelor's and Master's degree students can find full-time employment as Research Assistants to augment their research experience before or while applying to graduate schools.

Dear Colleagues and Friends:

The Preparatory Office of the Academia Sinica Institute of Astronomy and Astrophysics was established with the help of Academician Chia-Chiao Lin and Academy President Ta-You Wu. The rapid growth of our Institute in parallel with the development of astronomy and astrophysics in Taiwan can be traced to the generous support from the Academia Sinica, the Ministry of Education, and the National Science Council in Taiwan.

This pamphlet shows some of the research efforts at our Institute. Our emphasis has been on developing forefront technology and to engage in research on fundamental astrophysical problems. Our staff members pursue a variety of scientific initiatives, ranging from planet formation to black holes to cosmology. We work on observational investigations across all wavelength bands, theoretical studies utilizing both analytical and numerical methods, and instrumentation projects in the radio, optical, and infrared windows. The hard work of our scientists, engineers, students, and administrative staff, are reflected in the fascinating results sampled here. We hope we can communicate to you our excitement in working on the forefront problems in modern astronomy.

The success of our Institute has been guided by a succession of Directors, starting with Typhoon Lee, Chi Yuan, Kwok-Yung Lo, and Sun Kwok. We are grateful for the support of Academy Presidents Yuan-Tseh Lee and Chi-Huey Wong, and the guidance of our Advisory Panel chaired by Frank Shu.

Paul T. P. Ho 11.30.2007

The Submillimeter Array

The Submillimeter Array (SMA) project has been carried out by ASIAA in collaboration with the Smithsonian Astrophysical Observatory (SAO) since 1996. The array was dedicated on Mauna Kea, Hawaii in November 2003 by the previous Academia Sinica President Yuan Tseh Lee and the Smithsonian Institution Secretary Larry Small. It is a radio interferometer operating in the atmospheric windows centered at 230, 345, 400, and 690 GHz. It consists of eight 6 meter radio telescopes, with two of them (including the associated electronics and receiver systems) delivered by ASIAA under close collaborations with university groups and industry in Taiwan. The SMA is the first and currently the only array operating in submillimeter wavelengths. It provides us unique opportunities to observe warm, dense gas and dust at unprecedented high angular resolutions up to 0.1 arc seconds in extent. The research fields include the solar system, star and planet forming regions, evolved stars, and galaxies at nearby and cosmological distances.

As a partner of the SMA project, ASIAA contributes towards the maintenance and operation of the array. ASIAA has a small local staff residing in Hilo, Hawaii. In addition, the scientific and engineering staff visits the site regularly, and conducts remote operation from Taipei.

Figure 1. The Submillimeter Array, an eight-element radio telescope ensemble in the foreground of the figure, is currently one of the most powerful telescopes directly accessible by the astronomers in Taiwan. With its observing frequency of 180 - 690 GHz, the SMA is an unique instrument in the world. The observatories on the ridge, from left to right, are: Subaru Telescope, W. M. Keck Observatory, NASA Infrared Telescope Observatory (IRTF), and Canada-France-Hawaii Telescope (CFHT). (Picture credit: Derek Kubo)

Figure 2. The two telescopes built in Taiwan. (Picture credit: Ming-Tang Chen)

The Taiwan-America Occultation Survey

The Taiwan-America Occultaion Survey (TAOS) project is a collaboration among the ASIAA, the National Central Univeristy, the SAO (Alcock group previously at the Lawrence Livermore National Laboratory and the University of Pennsylvania), and the Yonsei University. TAOS has four 0.5 meter optical telescopes. All of them are now operating on Lu-Lin Mountain with their 2048 × 2048 CCD cameras tracking thousands of stars per night, searching for occultation by any intervening Trans-Neptunian object (TNO).

TNOs are small objects in our solar system beyond the orbit of Neptune. A study of TNOs may enable a better understanding of the origin of the short-period comets and of the process of planet formation and the early history of our solar system. Since most of them are only a few kilometers in size, a direct observation of reflected sunlight off them is extremely challenging. Currently, occultation is the only way to detect them at such a large distance.

Figure 3. Left: One of the TAOS 0.5 meter telescopes in its enclosure. Right: The four TAOS telescopes on top of Lu-Lin Mountain. Two of them are in the foreground. (Picture credit: S. K. King and H. C. Lin)

Spurious signals due to the atmosphere and equipment can be rejected by coincidence arguments with multiple telescopes running synchronously. Some 100 million stellar photometric measurements have been made. Upgrades to the cameras are being planned to increase the sensitivity of the surveys. The TAOS system is also capable of monitoring several other optical transient phenomena. It has resolved a previously unknown binary in an asteroid occultation event, detected an unexpected stellar flare, and recorded two Gamma ray burst (GRB) afterglows down to 16.5 magnitude in response to the GRB Coordinated Network.

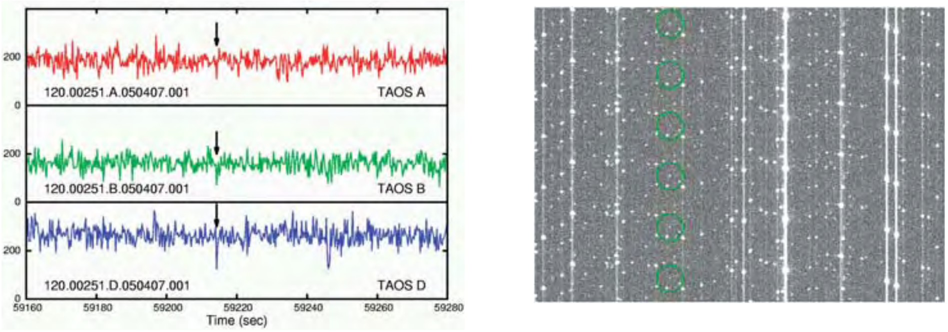


Figure 4. Left: The lightcurves from three telescopes for the possible occultation event detected by TAOS. The arrows show the synchronized drop of the stellar flux. Right: The images show a time sequence of the possible event. The green circle shows the star that had the flux change. (Picture credit: TAOS group)

The Yuan Tseh Lee Array for Microwave Background Anisotropy

The Yuan Tseh Lee Array for Microwave Background Anisotropy (AMiBA) is a forefront instrument for research in cosmology. This project is led, designed, constructed, and operated by ASIAA, with major collaborations with the Physics Department and Electrical Engineering Department of the National Taiwan University (NTU), and the Australia Telescope National Facility (ATNF). Additional contributions are also provided by the Carnegie Mellon University (CMU), the National Radio Astronomy Observatory (NRAO), and the Jet Propulsion Laboratory (JPL). The AMiBA is part of the Cosmology Particle Astrophysics (CosPA) initiative, led by NTU and funded by the Ministry of Education, the National Science Council and the Academia Sinica.

AMiBA is a dual-channel 85-105 GHz interferometer array of up to 19 elements, with full polarization capabilities. It can sample structures greater than 2 arc minutes in size. It targets specifically the distribution of high-redshift clusters of galaxies via the Sunyaev-Zel'dovich Effect (SZE), as a means to probe the primordial and early structure of the universe. AMiBA will also measure the polarization properties of the Cosmic Microwave Background (CMB), which is sensitive to the ionization history of the universe and can be a potential probe for gravity waves. It will improve upon the recent results from Wilkinson Microwave Anisotropy Probe (WMAP) by about a factor of 10 in angular resolution.

AMiBA is sited on Mauna Loa at an elevation of 3,400m in Hawaii. The construction of AMiBA includes a novel hexapod mount, a carbon fiber platform, carbon fiber reflectors, MMIC receivers, a broadband correlator, numerous electronics, a retractable cover, site infrastructures, and software development. The AMiBA has deployed the initial 7-element interferometer in Hawaii. A dedication ceremony was held in October 2006 on Mauna Loa, with previous AS President Y. T. Lee and NTU President S.C. Lee presiding. Science observations have started. An expansion to the 13-element configuration is underway, with deployment and testing in 2008.

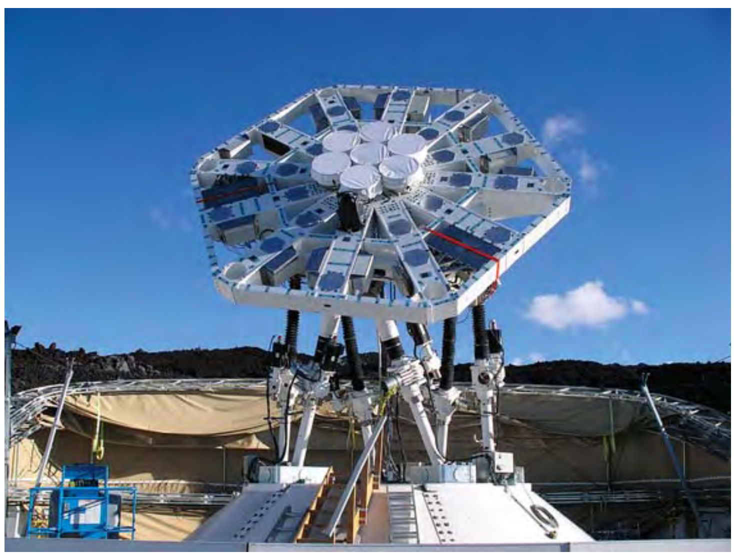


Figure 5. AMiBA on Mauna Loa, Hawaii in September 2006. Seven 60 centimeter antennas, covered with GoreTex sun protection shields, form the most compact configuration on the 6 meter carbon fiber platform. The optical telescope, correlator and associated mechanical and electronic packages can be seen mounted also on the platform. The hexapod jackscrew system can be seen attached to the platform. (Picture credit: Patrick Koch)

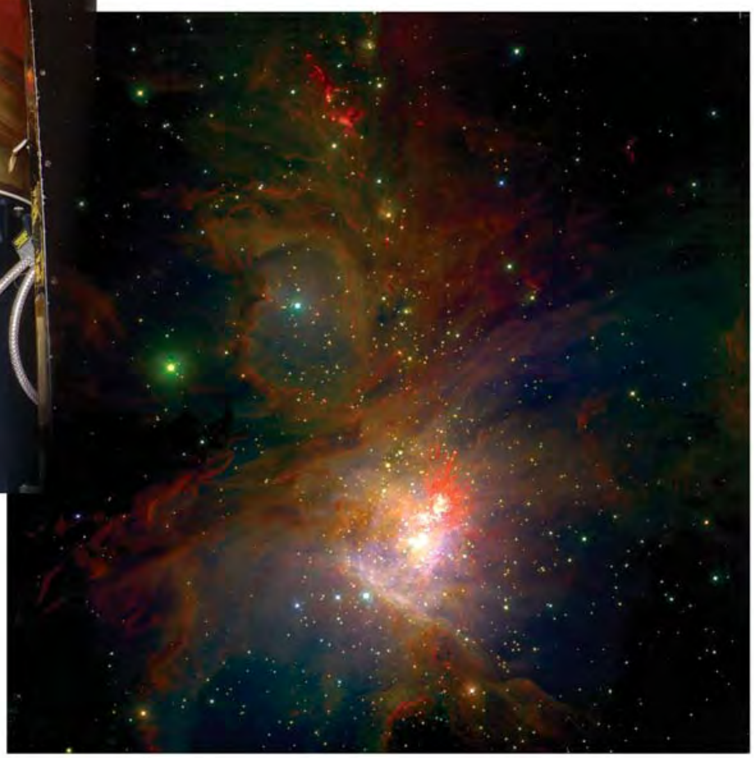
Figure 6. In the dedication ceremony of AMiBA held in Oct 2006, the NTU President S. C. Lee officially announced that the AMiBA is named as "Yuan Tseh Lee Array for Microwave Background Anisotropy" and presented the name plaque of the Array to previous AS President Y. T. Lee. (Picture credit: Fabi Roman)

The Optical and Infrared (OIR) Instrumentation Program

In order to support follow-up observations of high-redshift clusters detected in the AMiBA project and to train the next generation OIR astronomers, ASIAA negotiated for the observing time on the 3.6 meter Canada-France-Hawaii Telescope (CFHT) starting from 2003. This negotiation is a part of the CosPA effort together with the AMiBA development. Technical and financial contribution from ASIAA is in the form of support for the development of the Wide Field Infrared Camera (WIRCam). This camera was already installed and commissioned on CFHT in 2005. It has four 2048×2048 HcCdTe HAWAII-2RG detector arrays, with a 20 arc minute field of view, and a 0.3 arc second pixel scale. It is cooled to liquid nitrogen temperature to suppress the infrared background.

The experience with TAOS and WIRCam development has greatly advanced our capability to build world class optical and infrared instruments. ASIAA is now moving toward to the next instrumentation projects that will further enhance our capability. Participation of the next generation wide field CCD camera -- HSC (Hyper SuprimeCam) -- for the Subaru 8 meter telescope has been discussed with NAOJ, in which ASIAA will be responsible for delivering subsystems for the camera. ASIAA also joins the proposal for the feasibility study of next generation instrument (SPIROU) on CFHT. SPIROU will be an infrared spectropolarimeter that covers the full near infrared wavelengths (0.9~2.4 microns) in a single exposure.

Figure 7. Left: The WIRCam installed on the CFHT. Right: The Orion nebula image taken by WIRCam. (Picture credit: Shiang-Yu Wang and Canada-France-Hawaii Telescope/2006)



Theoretical Institute for Advanced Research in Astrophysics

The Theoretical Institute for Advanced Research in Astrophysics (TIARA) was established in 2004 to provide an integrated world class program of research and education in theoretical astrophysics. The institute is a cooperative effort between the National Science Council and Academia Sinica and aims to coordinate efforts of researchers and the training of future theoretical astrophysicists throughout Taiwan and Asia. It serves as an international center of excellence where forefront research can be intimately integrated into the graduate education at Taiwan's universities and academic institutions. Its primary facilities are located on the campus of National Tsing Hua University with a branch office at the Academia Sinica Institute of Astronomy and Astrophysics in Taipei.

Current affiliated members of TIARA include twenty-three faculty members and postdoctoral research fellows residing in Taiwan and North America, as well as four long term visitors from Asia and Europe. The research activities undertaken by the TIARA scientists span the fields of star formation, galactic dynamics, and high energy astrophysics including compact objects. In order to facilitate continuous intellectual stimulation, TIARA runs an active visitors program and organizes and hosts a vigorous series of topical workshops on especially timely areas. The most recent workshops focus on early solar system mixing and star formation. In addition, TIARA is playing a major role in improving the graduate education of students at universities throughout Asia by holding annual winter schools on special topics in Taiwan. The latest school offered an overview on astrophysical black holes, when approximately 50 students from Taiwan and abroad participated. A team of international experts on the subject was invited to deliver a total of 15 lectures. TIARA is continuing the series with a focus on extra solar plantes in 2008.

Figure 8. TIARA Early Solar System Mixing Workshop held in 2007.

Figure 9. Visitors Danielle Galli from Italy and Susana Lizano from Mexico working with Frank Shu on magnetized gravitational collapse.

Figure 10. TIARA Winter School - Astrophysical Black Holes in 2007.

Atacama Large Millimeter/Submillimeter Array - Taiwan

Since 2005 ASIAA has joined the Atacama Large Millimeter/Submillimeter Array (ALMA) project, the largest ground-based astronomical project ever carried out. The array is currently under construction in the Chajnantor area in the Atacama desert in northern Chile. ALMA will cover a wavelength range from 0.3 to 9 millimeters with an angular resolution of up to 4 milli-arc seconds, giving images 10 times sharper than the Hubble Space Telescope.

The ALMA project has three major international partners: North America, Europe, and Japan. The North American and European partners are responsible for the construction of the 12 meter Array (ALMA-baseline project), while Japan is responsible for the construction of the Atacama Compact Array (ACA; ALMA-Japan project). ASIAA has been participating in the ALMA Project through ALMA-Japan. Additional cooperation with ALMA-NA (North America) is under negotiation. ALMA will be completed in 2012, and its expected lifetime is at least 50 years.

ALMA will be enormously sensitive, and more than 10,000 times faster than any existing instrument at millimeter and submillimeter bands. The extremely high sensitivity of ALMA will allow us to study a broad range of exciting science such as weather patterns on the solar system planets, the formation of planets and stars in our galaxy, the gas motions within active galactic nuclei, and the formation of the earliest galaxies. For example, imaging protoplanetary disks around young Sun-like stars with resolution of a few astronomical units will enable us to detect the tidal gaps created by planets undergoing formation in the disks.

In addition to preparing for scientific projects for ALMA, ASIAA will also contribute to the construction of the array and associated engineering projects. For example, under collaboration with Chung-shan Institute of Science and Technology Aeronautical Systems Research Division (ASRD) in Taiwan, ASIAA has been establishing the East Asian Front-End Integration Center (EA-FEIC), where all the front-end subsystems for ACA will be assembled and evaluated, and then will be shipped to Chile.

Figure 11. The first three 12-meter antennas of ALMA-Japan constructed at the ALMA Operations Support Facility in Chile (picture credit: NAOJ).

Solar System

Comets are dirty snowballs that contain lots of dusts. They were believed to have formed in the outer solar system about 4.5 billion years ago, carrying important information about the early days of the solar system. The Stardust spacecraft of NASA, after seven years of journey, flew by Comet/Wild-2 and caught comet dusts near the nucleus for the very first time. The comet samples were returned to Earth on January 15, 2006.

The most striking discovery from the comet dusts is small particles that have formed under very high temperature (~1700˚C and possibly higher), similar to the Calcium-Aluminum Inclusions (CAI) found in carbonaceous meteorites, which were not local products made at the extreme cold (lower than −200˚C) of the outer solar system. These particles should have been melted and solidified in the central high-temperature region in the innermost proto-solar system (closer by 10 times from the distance of Mercury) and later transported to the outermost reaches of the solar nebula by a powerful bipolar outflow. This suggests that in the early solar system, large-scale and large-distance mixing and interactions for the matter between the inner and outer solar system existed, as predicted in our X-wind model of chondritic meteorites more than 10 years ago (Shu, Shang, & Lee, 1996, Science 271, pp1545-1552).

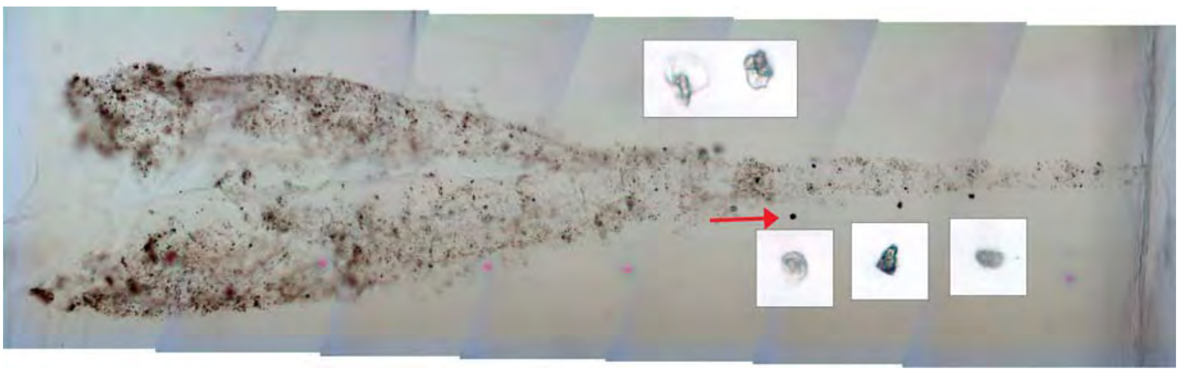


Figure 12. Comet samples collected by NASA Stardust spacecraft: small (<0.01 centimeters) particles entered from left, along a deceleration trajectory, and terminate on the right, making many fragments (small inserted pictures). The red arrow labels one particle that is like the CAI, believed to have formed under high temperature environment in the inner solar system. (Credit: NASA Johnson Space Center.)

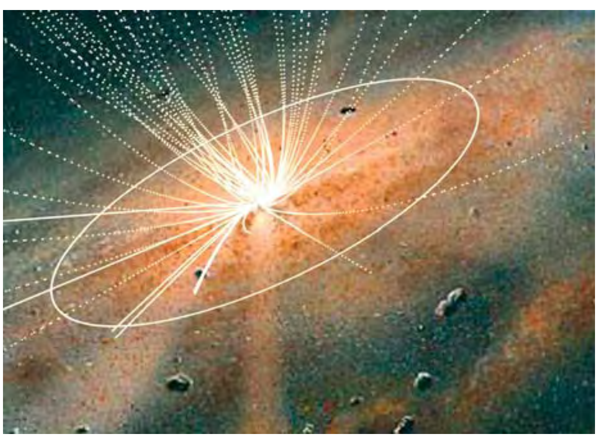


Figure 13. Shu, Shang, and Lee applied the X-Wind theory to the formation of high-temperature material in the early solar system (such as chondrules and CAIs from chondritic meteorites). The circle labels the very young solar system at 3AU, in which matter falls through, attracted by gravity, and accretes onto the forming young Sun. A fraction of the matter will turn into the X-Wind, launched along the dotted lines near the Sun. CAI particles of various sizes, whose trajectories are labelled by the solid lines, melted and solidified under high temperature, are thrown out by gas in the X-Wind, then detached and dropped like a fiery rain over the whole solar nebula. (Picture Credit: trajectory: Hsien Shang, background image: William K. Hartmann).

Low-mass Stars

The stars that we study here are lighter than our Sun. We discovered a wide pair of low-mass dwarf stars (Phan-Bao et al. 2007). Follow-up spectroscopic observations confirmed a spectral type of M0 (0.5 solar mass) for the primary (hereafter ASIAAa) and L0 (0.1 solar mass) for the secondary (hereafter ASIAAb). The projected separation between ASIAAa and ASIAAb is large, about 400 astronomical units (AU). The presence of Balmer line emission in ASIAAa indicates that the star is magnetically active. The wide binary provides us opportunities to test atmospheric theoretical models since the components are expected to have the same age and metallicity.

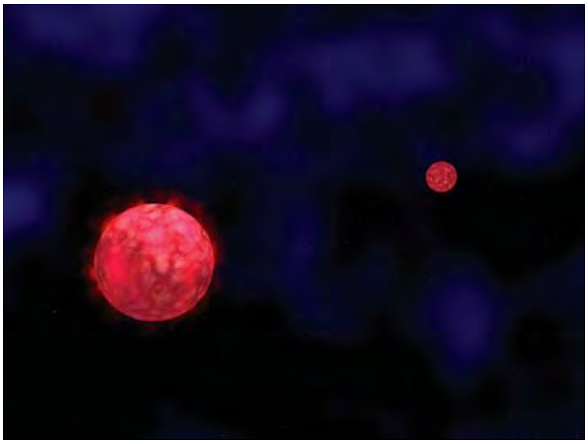


Figure 14. The wide binary: ASIAAa and ASIAAb (Credit ASIAA/Artwork by Change Tsai).

The ejection models of brown dwarf (very low mass, below 0.08 solar mass) formation predict that the binary brown dwarf systems that do exist must be close (separations ≦ 10 AU). We (Phan-Bao et al. 2005) discovered a wide very low-mass binary system, LP 714-37AB, consisting of two very low-mass (≦ 0.3 solar mass) dwarf stars with a projected separation of 33 AU (Figure 15, left panel). The existence of wide binaries is therefore at first sight inconsistent with the ejection model, suggesting that at least some very low-mass stars and brown dwarfs form through another process. A caveat, however, is that some apparent binaries might be unresolved triple or higher order multiple systems, whose additional components could boost the binding energy of the systems enough to allow them to survive ejection. Our follow-up adaptive optics observations of one such system, LP 714-37AB, did resolve the secondary into a tighter pair (Figure 15, right panel, Phan-Bao et al. 2006). The system LP 714-37 therefore demonstrates that some wide apparent very low-mass binaries are actually higher order multiple systems and no longer contradict the ejection scenario for brown dwarf formation.

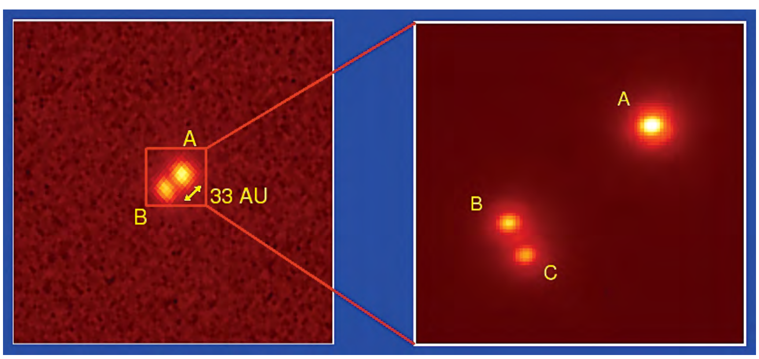
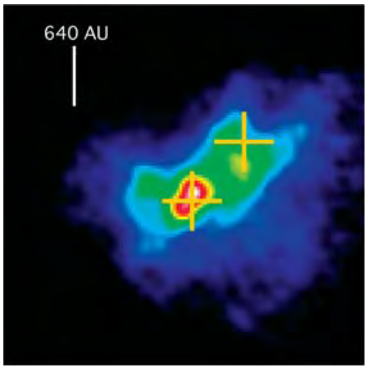


Figure 15. LP 714-37: A wide pair of ultracool dwarfs actually is a triple.

Star Formation

Stars including our Sun are basic building blocks of the Universe and it is important to understand where and how they come to be. It is believed that stars are formed inside dusty cocoons called "molecular cloud cores" by means of gravitational collapse. The details of the process, however, are complicated by the presence of magnetic field and angular momentum. We aim to advance our understanding of star formation by detailed studies toward nearby star-forming regions in our Galaxy, in observation and theory.

Dense condensations called "protostars" will first form in the beginning and then grow into stars in tens of million years as gas and dust continue to fall onto them. Interestingly, gas and dust are also found to be ejected rapidly from the protostars, forming bipolar jets emanating from them. The jets are now known to be the keys to remove excess angular momenta from the star-forming regions.



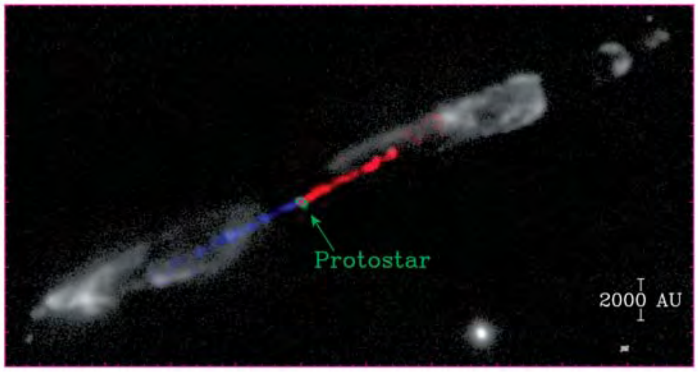
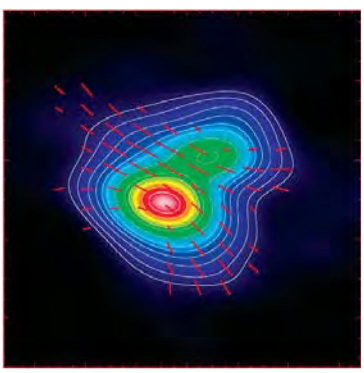


Figure 16. Left: Molecular gas in the star-forming region IRAS16293-2422 observed with the SMA and James Clerk Maxwell Telescope (JCMT). The gas is falling toward the protostars (cross marks) due to gravitational collapse (Takakuwa et al. 2007). Right: The bipolar (red for receding and blue for approaching sides) jet in the star-forming region HH 211 observed with the SMA (Lee et al. 2007). Gray image shows the shock emission produced by the jet (Hirano et al. 2006).

As a strong evidence of gravitational collapse, the magnetic fields in the molecular cloud cores are found forming hour-glass shapes around the protostars. In the close proximity of the protostars, magnetic fields are also believed to play a crucial role in channeling material onto the protostars and launching the jets. The X-wind model that accounts for such processes has been studied extensively in ASIAA. In this model, a magnetized accretion disk is formed around the protostar, from which part of the material is accreted by the protostar and part is ejected away. A numerical simulation with the model also produces a jet as seen in the observations (Shang et al. 2006).



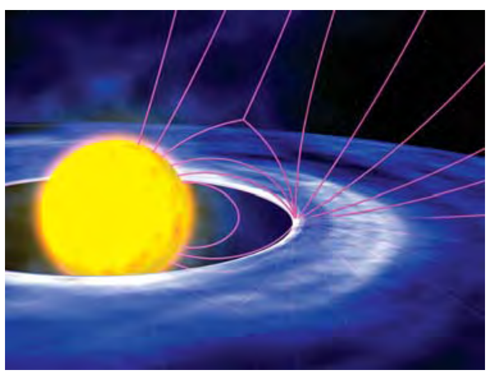


Figure 18. Left: The hour-glass shaped magnetic field (red dashed lines) seen by the SMA in the star-forming region NGC1333 IRAS4A (Girart, Rao, & Marrone 2006). Right: A schematic drawing of the X-wind model in the close proximity of the protostar (Picture credit by Mike Cai).

At the end of star formation, protoplanetary disks are seen around newly-born stars. They are the most promising sites for planet formation. The protoplanetary disk around the bright star, AB Aurigae, is promising because of its spiral arm structures. The rotation of the disk is found to depart noticeably from Keplerian motion, suggesting that there may indeed be a giant (Jupiter-sized) planet forming inside the disk responsible for the perturbation in morphology and kinematics, as seen in our simulation.

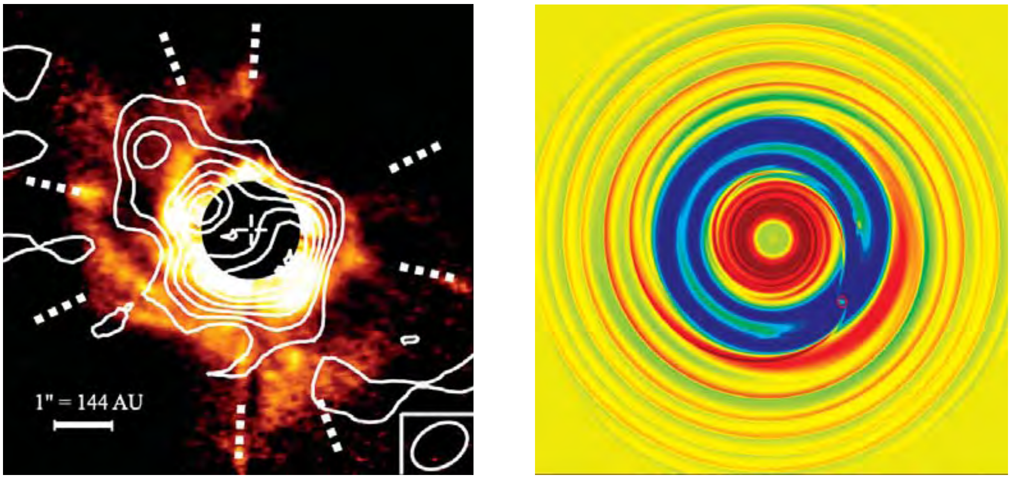
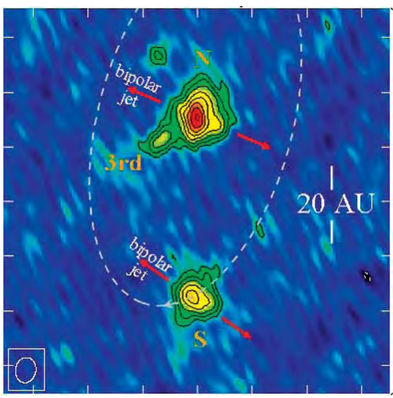


Figure 19. Left: Dust emission (contours) observed with the SMA and spiral arm structures (image) observed with the Subaru telescope in the protoplanetary disk of AB Aurigae (Lin et al. 2006). Right: Numerical simulation of a planet interacting with a protoplanetary disk (Zhang, Yuan, Lin, & Yen 2007, submitted).



Currently, it is still unclear why multiple protostars are often seen within a single protostellar system, for example, three protostars are seen in the protostellar system L1551 IRS 5. The disks associated with two of them are found to be aligned parallel to each other, as well as to their parent disk-like condensation of gas and dust. Our observation supports the popular yet hitherto unproven idea that multiple protostars form via fragmentation in the central region of their parent condensation.

Figure 20. The protosteller system L1551 IRS5 observed with the VLA. Red arrows denote bipolar jets. (Lim and Takakuwa 2006).

How high-mass stars (more than 8 times the mass of our Sun) form is still currently under debate. Our observation toward the high-mass protostar IRAS 20126+4104 clearly shows a bipolar outflow and a compact rotating disk surrounding the protostar. Similar to that seen toward the low-mass protostars, our observations suggest that the high-mass stars form the same way as the low-mass stars.

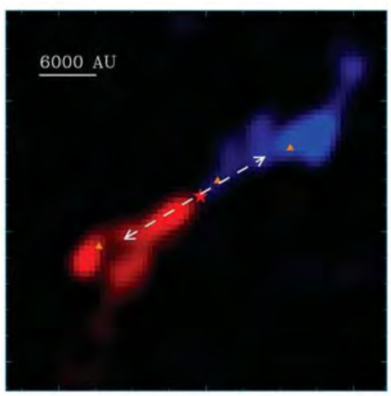


Figure 21. Bipolar outflow from the high-mass protostar IRAS 20126+4104 observed with the SMA. Red for receding and blue for approaching part of the outflow. (Su et al. 2007)

Evolved Stars

Most stars including our Sun will end their lives rapidly, evolving first into red gaint stars and then white dwarfs. Red giant stars represent a short but very important phase, during which the stars contribute significantly to the enrichment of the interstellar medium by ejecting most of their mass in the form of a slow and dusty wind. The study of circumstellar envelopes created by the mass ejection process has provided vital information for our understanding of the red giant phase and helped to elucidate different physical and chemical processes at work in the envelopes.

We have recently carried out a large and systematic spectral line survey toward a number of massive circumstellar envelopes using the radio telescope of the Arizona Radio Observatory. For example, in the envelope of the carbon star CW Leo, lines are seen mainly from carbon chain molecules such as cyanoacetylene HC_3N, butadiynyl radical C_4H, and silicon dicarbide SiC_2. We will study the chemical processes leading to the formation of such complex molecules.

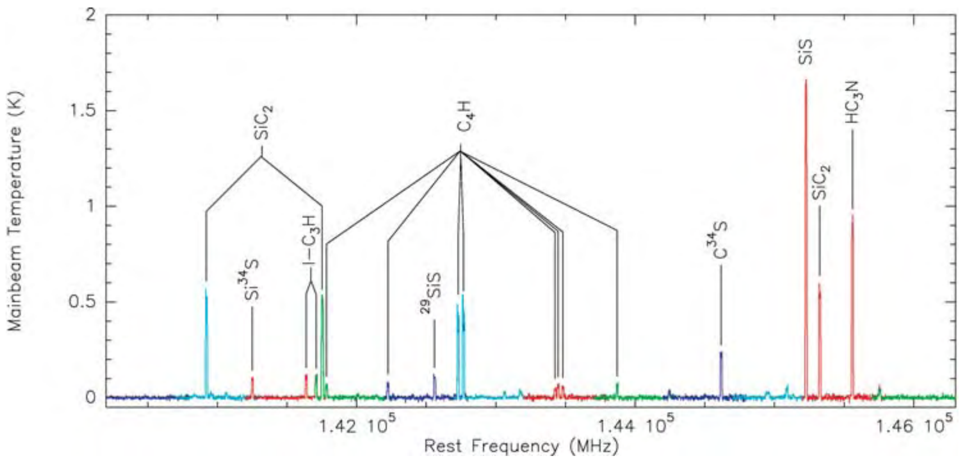


Figure 22. Spectrum toward the carbon star CW Leo, taken with the Arizona Radio Observatory 12 meter telescope (He et al. 2007).

The peculiar red supergiant VY Canis Majoris is interesting because of its highly complex circumstellar environment. With a detailed modeling, the molecular gas is found to possess two distinct kinematical components: a fast-moving bipolar outflow and a slowly-expanding spherical envelope (Muller et al. 2007).

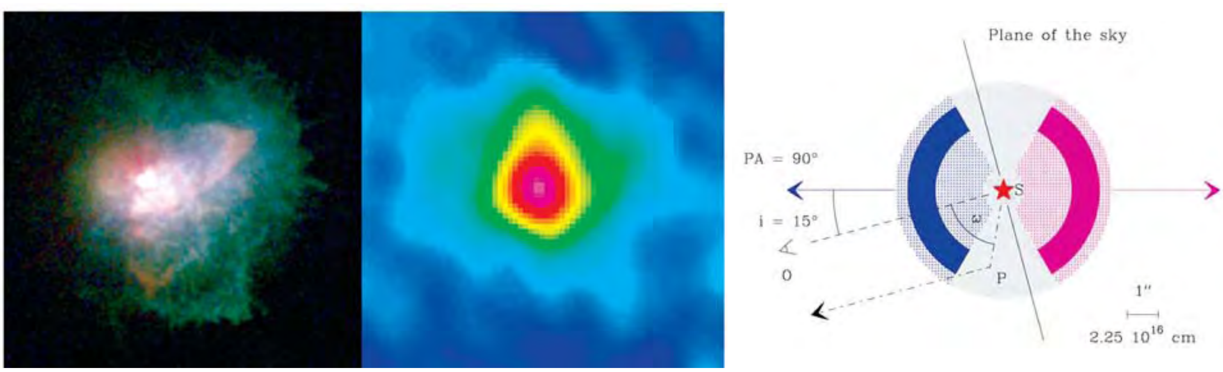


Figure 23. Left: HST optical image of VY Canis Majoris (Smith et al. 2001). Middle: Molecular gas around VY Canis Majoris observed with the SMA. Right: Structure of the gas with fast-moving bipolar outflow shown in red and blue colors. Red for receding and blue for approaching part of the outflow. (picture credit: Muller et al. 2007).

High Energy Astrophysics

Astronomical phenomena involving compact stellar objects are particularly fascinating since they can emit the greatest power in the Universe. Objects such as neutron stars and black holes are intrinsically of great interest as they are cosmic laboratories where their extreme conditions cannot be replicated terrestrially. As such they are critical for probing the state of matter at very high density and for probing the curvature of space time surrounding them.

We have interests in the origin and evolution of these stellar objects as well as the nature of the radiation they emit. Since these objects are so compact, they emit significant radiation at very high energies. For example, the rapidly rotating highly magnetized neutron stars, known as pulsars, are important sources of high energy gamma rays. Observations of such pulsars are used to provide information on the processes of particle acceleration under extreme conditions. An example of the particle-acceleration zone and the predicted gamma-ray emission properties are shown in figure 24 .

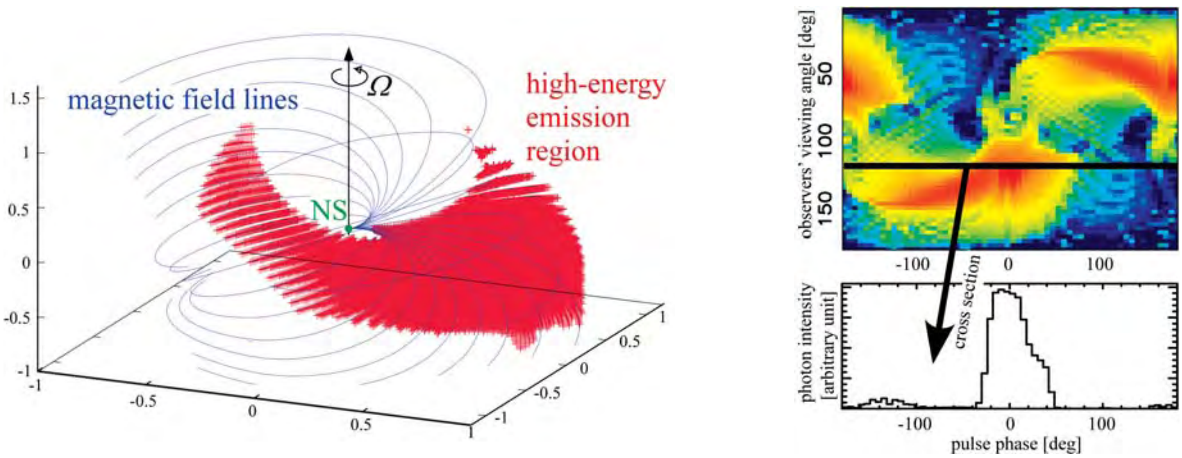


Figure 24. (left) Distribution of the emission region (red crosses) in a pulsar magnetosphere. The entire scale is a few thousand km. (right) Top: computed photon intensity on the pulse phase vs. observers' viewing angle plane, where the red region indicates the largest intensity. Bottom: predicted pulse profile during one spin period of the neutron star. (picture credit: Kouichi Hirotani)

Among the brightest stellar X-ray sources in our Galaxy as well as in external galaxies are binary star systems in which a compact black hole or neutron star member accretes matter from a stellar companion. In contrast to the pulsars, where energy is derived from the rotation of the neutron star, these sources derive their energy from the accretion of matter to their surface. Many such systems undergo transient outbursting phenomena allowing astronomers to observe a source over a wide range of conditions. Such observations have given astronomers a mental picture of the nature of the emission regions surrounding a black hole. A picture of the region of emission from a disk surrounding a black hole is illustrated in the following figure.

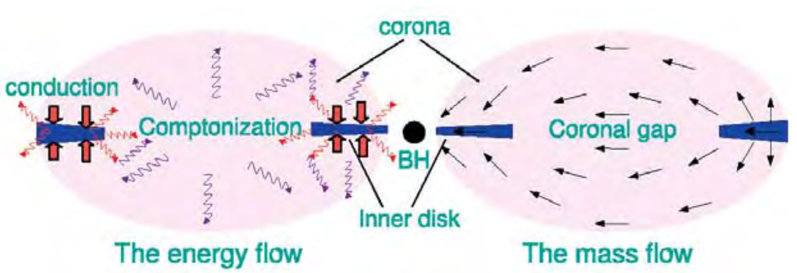


Figure 25. A schematic illustration of the mass and energy flow in a disk surrounding a black hole in a X-ray transient system in its quiescent state (see Liu, Taam, Meyer-Hofmeister, and Meyer 2007).

Extragalactic Studies

Active Galactic Nucleus (AGN) is believed to be the luminous visible evidence for the vigorous accretion of gas onto a super-massive black hole at the center of a galaxy. One important research activity is the study of molecular gas around AGNs. The general models suggest that molecular gas is rotating around AGN as a disk or a torus, but is this simple view true? Our high spatial resolution carbon monoxide (CO) gas observations toward nearby Seyfert galaxies with the SMA and other interferometers show very complicated molecular gas properties, and the gas near the AGN seems to be largely affected by the AGN activity.

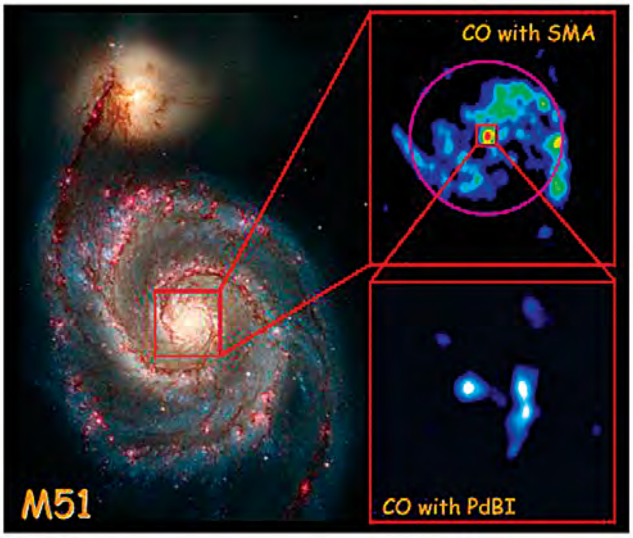


Figure 26. Our CO imaging studies of the nearby Seyfert galaxy M51 with the SMA and Plateau de Bure Interferometer (PdBI) show that the molecular gas distribution around the Seyfert nucleus is very complicated and show no clear evidence of a disk- or torus-like feature. [Left image: the HST Hubble Heritage (NASA, ESA, S. Beckwith and the Hubble Heritage Team). Bottom-right image: Matsushita, S., Muller, S., & Lim, J., 2007, A&A, 468, L49]

We are also studying the relation between molecular gas and star formation in galaxies. Stars are formed from molecular gas and in return the molecular gas is affected by radiation from stars. The observations of the distribution and properties for various molecular species therefore reveal the star formation activity. Our molecular gas observations toward a very active star-forming (starburst) galaxy show more active star formation than our Galaxy.

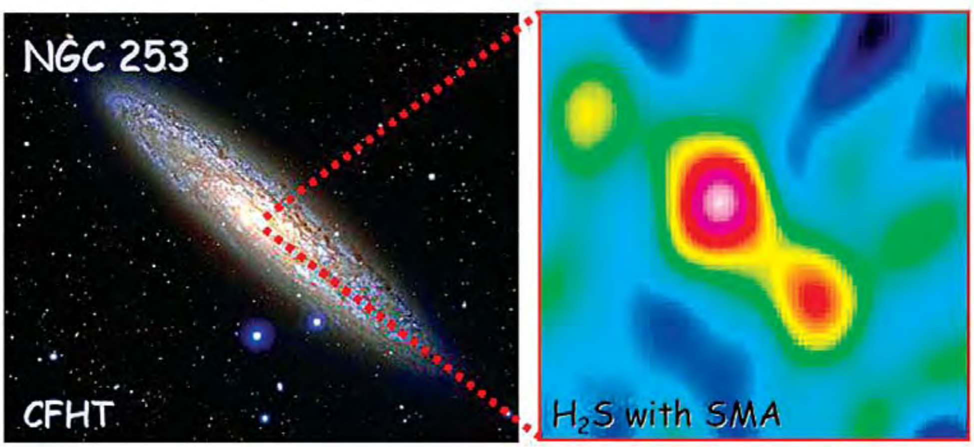


Figure 27. The H_2S image of the nuclear region of the nearby starburst galaxy NGC 253, as observed with the SMA. H_2S gas is believed to trace the on-going star formation activity. A rough scaling indicates that there might be thousands of star-forming cores each in the two brightest peaks [Left image: CFHT. Right image: Minh Y.C., Muller S., Liu S.-Y., & Yoon T.S., 2007, ApJ, 661, L135]

Cosmology

Cosmology is a study of the nature, origin, and evolution of the Universe. Theoretical models are constructed to describe our Universe and to provide us with specific predictions of physical phenomena, such as gravitational bending of light rays (gravitational lensing) and large-scale clustering of galaxies. Such models can be tested by comparing the predictions with astronomical observations.

A cosmology group has been assembled in support of the AMiBA project. The first AMiBA detection of the thermal Sunyaev-Zel'dovich (SZ) effect has been obtained towards the nearby massive cluster of galaxies, A2142. The thermal SZ effect is a direct probe of the thermal energy (pressure) content of the hot gas in clusters, and is a powerful tool for testing and obtaining a better understanding of cluster physics.

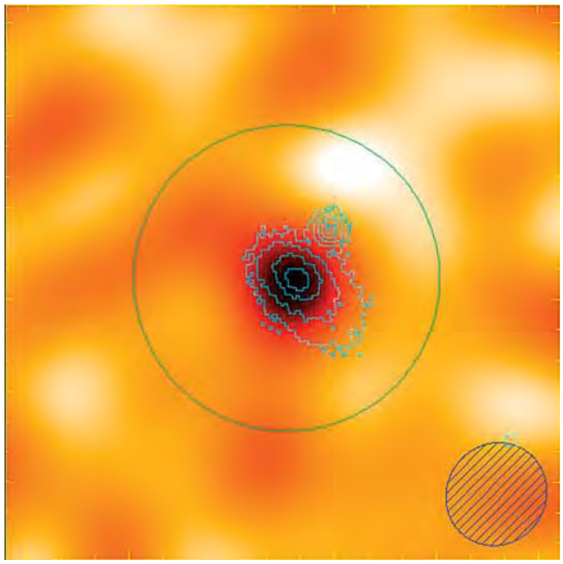


Figure 28. Abell 2142 is a nearby massive merging cluster of galaxies. The cluster is seen as a cold spot by the AMiBA. It is one of the brightest SZ sources on the sky due to its proximity and large mass (picture credit: Kyle Lin and AMiBA group)

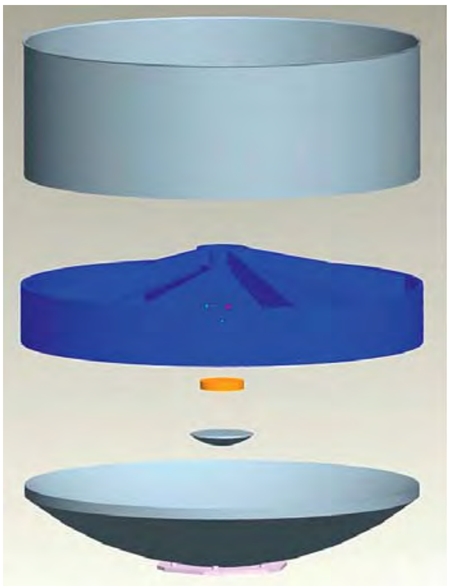
The cosmology group also makes use of other instruments such as the Subaru and the CFHT to pursue optical studies of distant clusters and large-scale structures of the Universe. Galaxy interactions and mergers play an important role in the evolution of galaxies. The merger history is directly related to how galaxies form and how the cosmic structures of the Universe, such as groups and clusters of galaxies, come to be. Therefore, by measuring the frequency of galaxy mergers and by studying the properties of interacting galaxies, we can place constraints on theoretical models of galaxy formation, which could further improve our understanding of cosmic structure formation in the Universe. We will use imaging data from the DEEP2 Redshift Survey and the Red-Sequence Cluster Survey to pin down the evolution of merger rates as a function of cosmic time, and to investigate how the present-day galaxies have evolved through mergers in the past 8 Gyr.

Figure 29: An HST image of one of the most famous interacting systems, the Antennae galaxies. Regions in pink indicate that a number of stars are being born triggered by the collision of two gas-rich galaxies [Picture Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration. Acknowledgement: B. Whitmore (Space Telescope Science Institute) and James Long (ESA/Hubble)].

Submillimeter Receiver Laboratory

The instrumentation research in ASIAA started with the establishment of the receiver laboratory in 1995, for the construction, testing, and integration of the SMA receiver. Since then, we have developed the expertise in the instrumentation of sensitive radio-wave receivers, which involves projects in the area of cryogenics, quasi-optics, microwave and millimeter-wave devices, analog and digital electronics, precision mechanical design and machining. Our core technologies focus on three important topics -- The superconductor-insulator-superconductor (SIS) junction design and fabrication, the development of monolithic microwave integrated circuit (MMIC), and the facilitation of complex receiver system design and integration.

In collaboration with various laboratories and experts in the world, we took on the technical driving role in the AMiBA project. In November 2002, the ASIAA receiver team has successfully established the AMiBA prototype receiver system on the site of Mauna Loa Observatory. In 2005, the telescope site infrastructure was completed, and the telescope mount was erected on Mauna Loa. The AMiBA 7-element was officially dedicated in October 2006. An expansion to the 13-element AMiBA is underway.



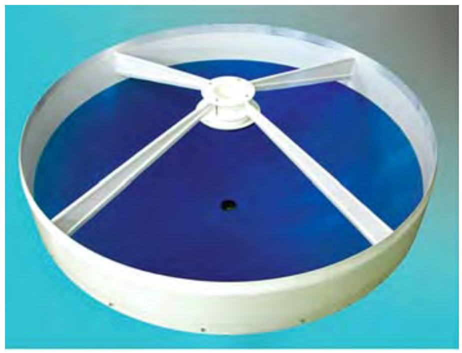


Figure 30. 1.2 meter Cassegrain antenna for AMiBA. The antenna structure is made of carbon fiber for its light weight. The reflective surfaces are aluminized plating with titanium-oxide protecting layer. In total, thirteen antennas will be made for the AMiBA project by CoTech Inc., in Taichung, Taiwan. (Provided by Ted Huang.)

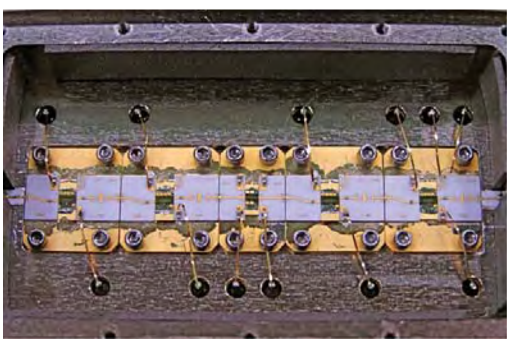


Figure 31. A prototyping System-on-Block for AMiBA intermediate frequency (IF). This is a newly developed methodology to miniaturize a fairly complex and bulky module into a block fitted in one's palm. Various MMIC devices with different functionality are pre-assembled with their associated circuitries (white substrates) on the gold-plated substrates. The substrates are then precisely aligned and integrated with the rest of the block to form a complex module. This is collaborative project between ASIAA and the Electrical Engineering Department of the National Taiwan University for replacement of the AMiBA IF system. (Provided by C. C. Han)

International collaboration is a key to today's ever-increasing complexity of instrumentation systems. We are constantly working with our colleagues from the National Radio Astronomy Observatory (NRAO, USA), the Australia Telescope National Facility (ATNF), the National Astronomical Observatory of Japan (NAOJ), the Purple Mountain Observatory of China (PMO), the Smithsonian Astrophysical Observatory (SAO), and experts in various universities in the US. Nationwide, we have teamed up with our colleagues in the National Taiwan University (NTU), National Tsing-Hua University (NTHU), the Chung-Shan Institute of Science and Technology, and experts in several local industries.

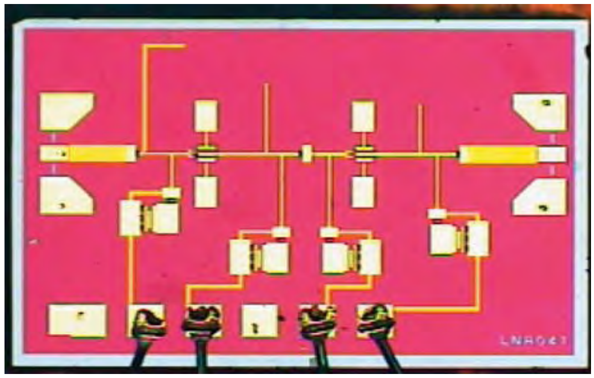


Figure 32. A prototype LNA chip covering 31 to 45 GHz. This chip comes from a developmental wafer run in the WIN semiconductors Inc., Taiwan, using a 0.15-micron mHEMT process based on their more mature pHEMT technologies. The measured noise figure of the chip ranges from 4 to 5 dB at room temperature. Measurements at low temperature are in preparation. (Provided by C. C. Chiong)

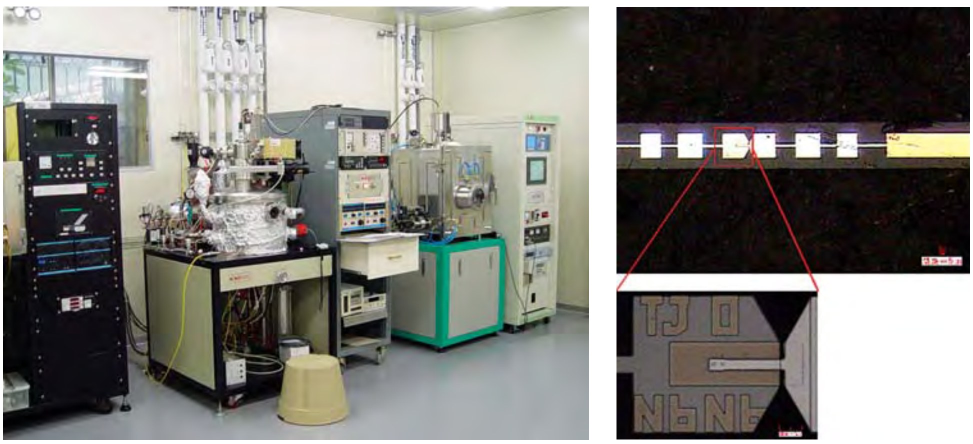


Figure 33. Left: The new clean room for mixer fabrication located at NTHU. Right: A niobium SIS mixer developed in ASIAA for SMA 850 GHz prototype and for ALMA band-10 receivers. The SIS fabrication facility in ASIAA securely supply the most important components for the SMA project. It also leads to technology development into new area of instrumentation, such as far-infrared detectors and SQUID. This is a collaborative effort between ASIAA and National Tsing Hua University, Taiwan. Internationally, we also collaborate with experts from the Purple Mountain Observatory in China, the National Astronomical Observatory of Japan, and the Smithsonian Astrophysical Observatory. (Picture credit: Ming-Jye Wang)

The ASIAA receiver group is constantly seeking opportunities to undertake challenging projects. Its role in ASIAA is not only to support the instrumentation effort, but also to stimulate thinking in new research directions, and to motivate our scientific members in ASIAA for new initiatives into unexplored regimes of the Universe. As a fairly young technical team, we are on fast learning curves of major technologies.

Optical/infrared Instrumentation Development

Building upon the experience in developing WIRCam for CFHT, the IAA has undertaken small local projects to enhance collaboration and relationship with the local industry in support of future large international collaborations. Two major projects are the InGaAs array development in cooperation with Chunghwa Telecom Corporation and the InAs quantum dots (QDs) IR detector development with National Chiao Tung University.

Large and high quality imaging arrays are the hearts of modern infrared astronomical instruments. A collaborative project was proposed by the Advanced Technology Research Laboratory of Chunghwa Telecom (ATR Lab.) to develop cheap alternative infrared arrays for astronomical applications. We worked with the ATR Lab to test the cryogenic characteristics of the InGaAs arrays. The ATR Lab provides 320 × 256 and 640 × 512 arrays with a cutoff wavelength around 1.7 microns for the project. The goal of current testing is to confirm the performance and packaging of the array under cryogenic temperatures. Further improvements of the arrays will be pursued after the performance of the arrays is well characterized.

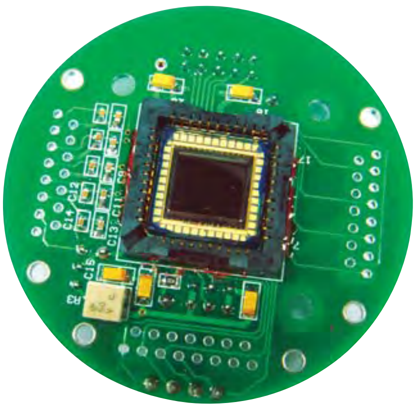
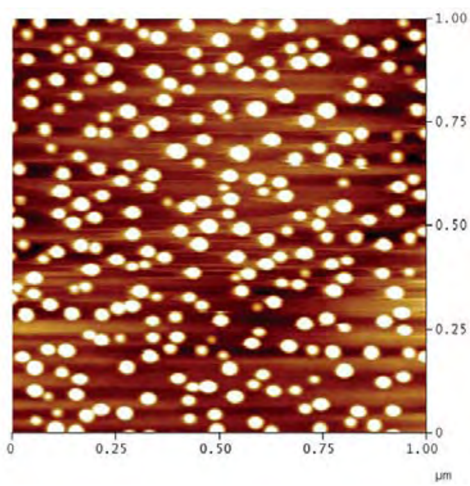


Figure 34. The interface board and the 320 × 256 InGaAs array for the characterization system.

Infrared detectors utilizing semiconductor QDs have been predicted to have the advantage of low cost and high operating temperature. With the self-assembled QDs, many efforts have been concentrated to improve the performance of quantum dot infrared photodetectors (QDIPs). However, by considering the repulsive potential generated by the charge inside the QDs, the capture probability, and thus the current gain, is shown to be greatly affected. With this idea, the charge of the carrier inside the QD can be calculated from the current gain. More work on the fabrication of such QDs has been undertaken. The manufacturing of an IR array with QDIPs is also planned.



In addition, an infrared camera project for the local Lulin 1 meter telescope has been initiated. With a HAWAII-1 array from CFHT, we plan to build the first IR astronomical camera in Taiwan as an exercise after the training of WIRCam.

Outreach Activities

ASIAA hosts outreach activities to improve the astronomical education of the public and to inform the general public of its achievements. These activities include the AS regular open house, a web server dedicated for posting major ASIAA achievements and worldwide astronomical news in Chinese, visits by high school students, astronomical talks for the public, and the "2007 Go to Hawaii" outreach activity.

AS open house activity

AS holds an open house every year, with the mission to explain to the public the exciting research activities conducted at the Academy. The event in 2007 involved about 25 ASIAA members including research fellows, research assistants, and administrative staff. To pique curiosity and inform the public, two popular talks titled "Making planets and the possibility of extraterrestrial life" and "The Three Hairs of Black holes" were presented to the audience who are mostly non-scientists. We also displayed several posters, exhibits, TV programs and remotely controlled our telescopes in Hawaii and on the summit of Lulin mountain. The audience received a first hand experience in astronomical research. To introduce the culture of Hawaii where the IAA radio telescopes are located, we invited the Hula Angel club to perform the traditional Hula dance.

Figure 36. A Hula Dance by Hula Angle club.

Figure 37. ASIAA research assistant explaining how astronomers observe stars by an hand-made optical telescope provided by Taipei Astronomical Museum.

ASWEB web server (http://asweb.asiaa.sinica.edu.tw)

Since October 2003, we have been maintaining a web site written in Chinese dedicated to the newest astronomical discoveries. The web server also provides a video-on-demand function to allow users to select and watch astronomical talks and lectures.

Figure 38. A snapshot of the ASWEB

Cooperation with the Taipei Astronomical Museum (TAM)

Encouraged by the success we enjoyed on open house days, we have developed a series of popular science talks for the general audience at the Taipei Astronomical Museum starting from May 2006. These talks are aimed at senior high school teachers and students in astronomical clubs. The audience can discuss the presentation with the speaker face-to-face after a talk. All talk information and materials are collected and displayed on the web (http://asweb.asiaa.sinica.edu.tw).

Figure 39. A popular science talk at TAM.

Video production with the Public Television Service Foundation

Since 2005, ASIAA and the Public Television Service Foundation have collaborated in producing three astronomical TV programs. They are “Explore the unknown-SMA”, “Galaxies waving their spiral arms” and “Comets: The ancient fossils in the solar system”. All these TV programs serve to highlight ASIAA's achievements as well as promote its visibility in the community.

Figure 40. Consisting of eight 6 meter antennas, the SMA can simulate a 508 meter single dish telescope. The above is an artist's conception of such a single dish telescope, which occupies an area equivalent to nine football fields. (Picture credit: Public Television Service Foundation)

2007 Go to Hawaii

Astronomy is in its golden age. Taiwan is engaged in the front line of astronomical research. To share our discoveries and our work with the young people of Taiwan, ASIAA invited two senior high school teachers to visit SMA and AMiBA in Hawaii July 2007. ASIAA strives to impress the young people that the whole universe is in front of them. Formosa TV Station recorded this visit and made a 15 minute TV program.

Figure 41. Top: Students in Academia Sinica talking with their teachers in SMA control room by video conference. Bottom: Two senior high school teachers and two journalists with our colleagues, taken in Hawaii.

Education

One of the central missions of ASIAA is to help educate and train the next generation of Taiwanese astronomers. We work in close coordination with universities to encourage and support their students to engage in front-line research in astronomy. While ASIAA does not provide its own degree program, many graduate students are working for their degrees under joint supervision of ASIAA faculty members and professors in their own universities. Many of the research activities at ASIAA are conducted in collaboration with universities in Taiwan and abroad. Joint research projects, seminars and conferences, visitor programs, and adjunct appointments, are part of the ASIAA effort to cooperate with universities. ASIAA also organized an Interferometer School in 2006, specifically for students who are interested in using radio interferometers such as SMA and ALMA for their research.

Summer Student Program

For undergraduate students interested in astronomy, ASIAA offers a Summer Student Program to introduce modern astronomical research experiences. A selected student typically works on a specific topic under the supervision of our research staff for two months. One of the major purposes of this program is to provide the opportunity for students to learn, at first hand, the various aspects of an advanced astronomical research program. A series of lectures are also offered to broaden the exposure of the students to different research topics. Many summer students continue their research after the summer program. Website: http://www.asiaa.sinica.edu.tw/Education/ SummerStudents/

Figure 42. Left: The supervisors having lunch with their summer students on the first day of the 2007 summer program. Right: The 2007 summer student s attending a summer lecture.

Open Opportunities for Undergraduate/Graduate Student

ASIAA provides a rich opportunity for students at all levels to carry out frontier research under the supervision of Institute scientists. Talented undergraduate students can find part-time employment to conduct research with a selected mentor. This provides a deeper and richer research experience which is important preparation for future graduate studies. Talented Bachelor's and Master's degree students can find full-time employment as Research Assistants to augment their research experience before or while applying to graduate schools.