The new year started off with a bang with a video presentation on everyone’s favorite planet, dwarf or otherwise, Pluto. The video is the first of a two-part series bracketing the February birthday of Clyde Tombaugh 101 years ago and the discovery of Pluto on Feb. 18th, 87 years ago. Part II will be a talk at our Feb. meeting (see the poster on pg. 5) on the latest attempts to find a successor to Pluto as the 9th planet in the solar system.

After an extended absence of any serious discussion of so-called planet X, recent research has not only indicated the existence of such an object, but has also supplied possible places to look for the purported challenger to the throne based upon technology and observations that Clyde Tombaugh would never have believed possible.

As always, we will again attempt to observe the heavens if the weather

(Continued on page 2)
About the Astronomy Associates of Lawrence

The club is open to all people interested in sharing their love for astronomy. Beginning in Fall 2016, monthly meetings are typically on the last Sunday of each month and often feature guest speakers, presentations by club members, and a chance to exchange amateur astronomy tips. These meetings and the public observing sessions that follow are scheduled at the Baker Wetlands Discovery Center, south of Lawrence. All events and meetings are free and open to the public. Periodic star parties are scheduled as well. For more information, please contact the club officers: president, Rick Heschmeyer at rcjbm@sbcglobal.net; AlCor William Winkler, at billwink10@yahoo.com; or faculty advisor, Prof. Bruce Twarog at btwarog@ku.edu. Because of the flexibility of the schedule due to holidays and alternate events, it is always best to check the Web site for the exact Sundays when events are scheduled. The information about AAL can be found at

http://www.physics.ku.edu/AAL/

Copies of the Celestial Mechanic can also be found on the web at

http://www.physics.ku.edu/AAL/newsletter

(Continued from page 1)

Shallow Sky Object of the Month:
Aldebaran – the eye of the bull
Bill Pellerin, Houston Astronomical Society

Object: Aldebaran (SAO 94027)
Class: Orange giant star
Constellation: Taurus
Magnitude: 0.87
R.A.: 04 h, 35 m, 55 s
Dec: 16° 30' 30"
Size/Spectral: K5 (4100k temperature)
Distance: 65 ly
Optics needed: Unaided eye

When you see the constellation Taurus and the nearby and popular constellation of Orion you know it’s winter. Well winter officially began at 10:44 a.m. (UT) on December 21. Those of us who live in the southern United States are now having days of cool temperatures and days of warm temperatures while the weather figures out what season it wants to be. Northerners are, according to news reports, having quite cold weather and some snow. If it’s too cold for you to get outside and set up your telescope for an extended observing session there are still plenty of objects to admire with a quick visit to the back yard. The object this month is a very bright star, obvious to the unaided eye in the constellation Taurus. Al-

Speaking of observing, there is a penumbral eclipse of the moon on tap for Feb. 10. See the story below for more info. The beauty of these events is that no telescope is required.

Following up on our discussion in the Fall of possible public education events for this semester, Rick reports that the Girl Scout/Boy Scout Astronomy event that he has been working on is not going to happen this semester. However, Rick is continuing his conversation with the Girl Scout Council office in Kansas City and the Fall remains a possibility. More info will be passed along as soon as we have any. With the start of the New Year, we also have our annual ritual of collecting club dues: $6 for students and $12 for everyone else. I will send out the club form via email in a few days so that it doesn’t get lost as an addendum buried within the newsletter. Please remember if you send a check to make it out to KUEA.

Any suggestions for improving the club or the newsletter are always welcome.
debaran, a K star, stands out for both its brightness and its color, a bright orange / red that's not duplicated by any nearby stars. To see a redder star, look to Betelgeuse, which is a M class star.

So, what are we looking at here? Aldebaran is slightly variable, from .75 magnitude to .95 magnitude, but this change in magnitude is not easily visible to anyone making visual observations. A photometric observer could detect this change, but a quick check of the AAVSO (American Association of Variable Star Observers) finds no data for this star submitted.

Aldebaran is close enough to the ecliptic that there are times when the Moon occults (moves in front of) the star. It would also be true that the Sun can occult the star, but it would be impossible to observe this occultation for obvious reasons. There’s an occultation of Aldebaran on March 4, 2017 beginning at 7:53:22.9 Central time and ending on March 5, at 00:04:50.5 Central time. For this occultation, the Moon will be at first quarter. This is a long duration occultation because the star goes almost directly behind the moon.

Usually, when a star is occulted by the Moon it simply winks out. It’s there one instant and in the next instant it’s not there. Aldebaran is .02 arc-seconds on the sky and has been reported by observers to not wink out in the same way that other stars do, perhaps taking as much as .02 seconds to disappear. Can you see this?

In the finder chart associated with this article, note that the ecliptic (blue line) is north of Aldebaran. As we all know, the Moon’s path through the sky is close to, but not on the ecliptic. What else can we see while we’re waiting for the occultation?

When we observe Aldebaran with binoculars or a wide field telescope we're looking into the Hyades cluster, considered by some to be the ‘sister’ cluster to the nearby Pleiades cluster. Aldebaran is not a member of the Hyades cluster, however. The cluster is about twice as far from us as is Aldebaran. It’s very pretty to see this cluster on a dark night. Our understanding of stellar evolution tells us that Aldebaran has evolved and is no longer on the main sequence, the mid-life of stars. This means that hydrogen burning is no longer taking place at the core of the star, and helium is now powering the star. A hydrogen shell is still burning at an outer layer of the star, however.

Whether Aldebaran is the host star for a planet, or a planetary system, is still under discussion. Some wobble has been detected in the star, and this wobble could be associated with the tug of a planet, but it is also believed that that some of this wobble may be intrinsic to the star going through the transition from a main sequence star to a red giant.
Comet Campaign: Amateurs Wanted

By Marcus Woo

In a cosmic coincidence, three comets will soon be approaching Earth—and astronomers want you to help study them. This global campaign, which will begin at the end of January when the first comet is bright enough, will enlist amateur astronomers to help researchers continuously monitor how the comets change over time and, ultimately, learn what these ancient ice chunks reveal about the origins of the solar system.

Over the last few years, spacecraft like NASA's Deep Impact/EPOXI or ESA's Rosetta (of which NASA played a part) discovered that comets are more dynamic than anyone realized. The missions found that dust and gas burst from a comet's nucleus every few days or weeks—fleeting phenomena that would have gone unnoticed if it weren't for the constant and nearby observations. But space missions are expensive, so for three upcoming cometary visits, researchers are instead recruiting the combined efforts of telescopes from around the world.

"This is a way that we hope can get the same sorts of observations: by harnessing the power of the masses from various amateurs," says Matthew Knight, an astronomer at the University of Maryland.

By observing the gas and dust in the coma (the comet's atmosphere of gas and dust), and tracking outbursts, amateurs will help professional researchers measure the properties of the comet's nucleus, such as its composition, rotation speed, and how well it holds together.

The observations may also help NASA scout out future destinations. The three targets are so-called Jupiter family comets, with relatively short periods just over five years—and orbits that are accessible to spacecraft. "The better understood a comet is," Knight says, "the better NASA can plan for a mission and figure out what the environment is going to be like, and what specifications the spacecraft will need to ensure that it will be successful."

The first comet to arrive is 41P/Tuttle-Giacobini-Kresak, whose prime window runs from the end of January to the end of July. Comet 45P/Honda-Mrkos-Pajdusakova will be most visible between mid-February and mid-March. The third target, comet 46P/Wirtanen won't arrive until 2018.

Still, the opportunity to observe three relatively bright comets within roughly 18 months is rare. "We're talking 20 or more years since we've had anything remotely resembling this," Knight says. "Telescope technology and our knowledge of comets are just totally different now than the last time any of these were good for observing."

For more information about how to participate in the campaign, visit http://www.psi.edu/41P45P46P. Want to teach kids about the anatomy of a comet? Go to the NASA Space Place and use Comet on a Stick activity! http://spaceplace.nasa.gov/comet-stick/
Dr. Bruce Twarog
Department of Physics & Astronomy, KU

SUNDAY FEBRUARY 26
7:00 PM
BAKER WETLANDS DISCOVERY CENTER
Telescope Observing - 8:00 PM
Free and Open to the Public
Gaia turns its eyes to asteroid hunting

Whilst best known for its surveys of the stars and mapping the Milky Way in three dimensions, ESA's Gaia has many more strings to its bow. Among them, its contribution to our understanding of the asteroids that litter the Solar System. Now, for the first time, Gaia is not only providing information crucial to understanding known asteroids, it has also started to look for new ones, previously unknown to astronomers.

Since it began scientific operations in 2014, Gaia has played an important role in understanding Solar System objects. This was never the main goal of Gaia— which is mapping about a billion stars, roughly 1% of the stellar population of our Galaxy— but it is a valuable side effect of its work. Gaia's observations of known asteroids have already provided data used to characterise the orbits and physical properties of these rocky bodies more precisely than ever before.

"All of the asteroids we studied up until now were already known to the astronomy community," explains Paolo Tanga, Planetary Scientist at Observatoire de la Côte d'Azur, France, responsible for the processing of Solar System observations.

These asteroids were identified as spots in the Gaia data that were present in one image and gone in one taken a short time later, suggesting they were in fact objects moving against the more distant stars. Once identified, moving objects found in the Gaia data are matched against known asteroid orbits to tell us which asteroid we are looking at. "Now," continues Tanga, "for the first time, we are finding moving objects that can't be matched to any catalogued star or asteroid."

The process of identifying asteroids in the Gaia data begins with a piece of code known as the Initial Data Processing (IDT) software—which was largely developed at the University of Barcelona and runs at the Data Processing Centre at the European Space Astronomy Centre (ESAC), ESA's establishment in Spain.

This software compares multiple measurements taken of the same area and singles out objects that are observed but cannot be found in previous observations of the area. These are likely not to be stars but, instead, Solar System objects moving across Gaia's field of view. Once found, the outliers are processed by a software pipeline at the Centre National d'Études Spatiales (CNES) data centre in Toulouse, France, which is dedicated to Solar System objects. Here, the source is cross matched with all known minor bodies in the Solar System and if no match is found, then the source is either an entirely new asteroid, or one that has only been glimpsed before and has never had its orbit accurately characterised.

Although tests have shown Gaia is very good at identifying asteroids, there have so far been significant barriers to discovering new ones. There are areas of the sky so crowded that it makes the IDT's job of matching observations of the same star very difficult. When it fails to do so, large numbers of mismatches end up in the Solar System objects pipeline, contaminating the data with false asteroids and making it very difficult to discover new ones.

"At the beginning, we were disappointed when we saw how cluttered the data were with mismatches," explains Benoit Carry, Observatoire de la Côte d'Azur, France, who is in charge of selecting Gaia alert candidates. "But we have come up with ways to filter out these mismatches and they are working! Gaia has now found an asteroid barely observed before."
The asteroid in question, nicknamed Gaia-606, was found in October 2016 when Gaia data showed a faint, moving source. Astronomers immediately got to work and were able to predict the new asteroid’s position as seen from the ground over a period of a few days. Then, at the Observatoire de Haute Provence (southern France), William Thuillot and his colleagues Vincent Robert and Nicolas Thouvenin (Observatoire de Paris/IMCCE) were able to point a telescope at the positions predicted and show this was indeed an asteroid that did not match the orbit of any previously catalogued Solar System object. However, despite not being present in any catalogue, a more detailed mapping of the new orbit has shown that some sparse observations of the object do already exist. This is not uncommon with new discoveries where, as with Gaia-606 (now renamed 2016 UV56), objects that first appear entirely new transpire to be re-sightings of objects whose previous observations were not sufficient to map their orbits.

“This really was an asteroid not present in any catalogue, and that is an exciting find!” explains Thuillot. “So whilst we can’t claim this is the first true asteroid discovery from Gaia, it is clearly very close and shows how near we are to finding a never-before-seen Solar System object with Gaia.”

Gaia-606 was found in the main asteroid belt, which is not surprising given how many asteroids exist there. However, Gaia also provides data from swaths of the sky not extensively observed by existing ground-based surveys giving it the potential to find asteroids in areas where others would not look. One such area is a region close to the Sun as seen from Earth. Observations are made from the Earth during the night when the angle between any source and the Sun is fairly large, whilst Gaia can make observations at any time and so observe objects much closer to the Sun. This gives Gaia the exciting potential to observe asteroids that orbit within Earth’s orbit – these are known as Atira asteroids and only sixteen are currently known.

Gaia also has the potential to make discoveries at high ecliptic latitudes. Not because ground-based surveys of Solar System objects cannot observe there, but because they tend not to. The vast majority of asteroids exist in the ecliptic plane and, as a result, it is here that most surveys concentrate their efforts. Gaia has no such prejudices and scans the entire sky, giving it the potential to discover new asteroids in the less crowded areas missed by other surveys.

“Whilst Gaia’s primary role in Solar System science remains its ability to characterise the movement and physical properties of known asteroids, it has now shown that it can also play a role in finding new ones, adding to its ever expanding catalogue of Solar System objects,” concludes Tanga.

![Gaia's detections of asteroids in eight months' worth of data, compared with the positions on the sky of a sample of 50,000 known asteroids. The colour of the data points is an indication of the accuracy of the detections, showing the separation on the sky between the observed position of Gaia's detection and the expected position of each asteroid: blue indicates higher accuracy, whereas green and red indicate lower accuracy. The regions showing lower accuracy of asteroid detections correspond to patches of the sky where the stellar density is very high, thus complicating the identification process.](image)
Astronomers Discover Powerful Cosmic Double Whammy

Astronomers have discovered a cosmic one-two punch unlike any ever seen before. Two of the most powerful phenomena in the Universe, a supermassive black hole, and the collision of giant galaxy clusters, have combined to create a stupendous cosmic particle accelerator. By combining data from NASA’s Chandra X-ray Observatory, the Giant Metrewave Radio Telescope (GMRT) in India, the NSF’s Karl G. Jansky Very Large Array, and other telescopes, researchers have found out what happens when matter ejected by a giant black hole is swept up in the merger of two enormous galaxy clusters.

“We have seen each of these spectacular phenomena separately in many places,” said Reinout van Weeren of the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Mass., who led the study that appears in the inaugural issue of the journal Nature Astronomy. “This is the first time, however, that we see them clearly linked together in the same system.”

This cosmic double whammy is found in a pair of colliding galaxy clusters called Abell 3411 and Abell 3412 located about two billion light years from Earth. The two clusters are both very massive, each weighing about a quadrillion — or a million billion — times the mass of the Sun.

This composite image contains X-rays from Chandra (blue) that reveal diffuse emission from multi-million-degree gas in the two clusters. The comet-shaped appearance of the hot gas provides clear evidence that the two clusters are colliding and merging. The "head" of the comet is hot gas from one cluster plowing through the hot gas of the other cluster.

Japan’s Subaru telescope, both on Mauna Kea, Hawaii, detected the galaxies in each cluster.

First, at least one spinning, supermassive black hole in one of the galaxy clusters produced a rotating, tightly-wound magnetic funnel. The powerful electromagnetic fields associated with this structure have accelerated some of the inflowing gas away from the vicinity of the black hole in the form of an energetic, high-speed jet.

Then, these accelerated particles in the jet were accelerated again when they encountered colossal shock waves — cosmic versions of sonic booms generated by supersonic aircraft — produced by the collision of the massive gas clouds associated with the galaxy clusters.

"It's almost like launching a rocket into low-Earth orbit and then getting shot out of the Solar System by a second rocket blast," said co-author Felipe Andrade-Santos, also of the CfA. "These particles are among the most energetic particles observed in the Universe, thanks to the double injection of energy."

This discovery solves a long-standing mystery in galaxy cluster research about the origin of beautiful swirls of radio emission stretching for millions of light years, detected in Abell 3411 and Abell 3412 with the GMRT. The team determined that as the shock waves travel across the cluster for hundreds of millions of years, the doubly accelerated particles produce giant swirls of radio emission.

"This result shows that a remarkable combination of powerful events generate these particle acceleration factories, which are the largest and most powerful in the Universe," said co-author William Dawson of Lawrence Livermore National Lab in Livermore, Calif. "It is a bit poetic that it took a combination of the world’s biggest observatories to understand this."
Hubble Detects 'Exocomets' Taking the Plunge into a Young Star

Interstellar forecast for a nearby star: Raining comets! NASA's Hubble Space Telescope has discovered comets plunging into the star HD 172555, which is a youthful 23 million years old and resides 95 light-years from Earth.

The exocomets — comets outside our solar system — were not directly seen around the star, but their presence was inferred by detecting gas that is likely the vaporized remnants of their icy nuclei.

HD 172555 represents the third extrasolar system where astronomers have detected doomed, wayward comets. All of these systems are young, under 40 million years old.

The presence of these doomed comets provides circumstantial evidence for "gravitational stirring" by an unseen Jupiter-size planet, where comets deflected by the massive object's gravity are catapulted into the star. These events also provide new insights into the past and present activity of comets in our solar system. It's a mechanism where infalling comets could have transported water to Earth and the other inner planets of our solar system.

Astronomers have found similar plunges in our own solar system. Sun-grazing comets routinely fall into our sun. "Seeing these sun-grazing comets in our solar system and in three extrasolar systems means that this activity may be common in young star systems," said study leader Carol Grady of Eureka Scientific Inc., in Oakland, California, and NASA's Goddard Space Flight Center in Greenbelt, Maryland. "This activity at its peak represents a star's active teenage years. Watching these events gives us insight into what probably went on in the early days of our solar system."

(Continued on page 10)
solar system, when comets were pelting the inner solar system bodies, including Earth. In fact, these star-grazing comets may make life possible, because they carry water and other life-forming elements, such as carbon, to terrestrial planets."

The star is part of the Beta Pictoris Moving Group, a collection of stars born from the same stellar nursery. It is the second group member found to harbor such comets. Beta Pictoris, the group’s namesake, also is feasting on exocomets travelling too close. A young gas-giant planet has been observed in that star's vast debris disk.

The Beta Pictoris Moving Group is important to study because it is the closest collection of young stars to Earth. At least 37.5 percent of the more massive stars in the group either have a directly imaged planet, such as 51 Eridani b in the 51 Eridani system, or infalling star-grazing bodies, or, in the case of Beta Pictoris, both types of objects. The grouping is around the age where it should be building terrestrial planets, Grady said.

A team of French astronomers first discovered exocomets transiting HD 172555 in archival data gathered between 2004 and 2011 by the European Southern Observatory's HARPS (High Accuracy Radial velocity Planet Searcher) spectrograph. A spectrograph divides light into its component colors, allowing astronomers to detect an object’s chemical makeup. The HARPS spectrograph detected the chemical fingerprints of calcium imprinted in the starlight, evidence that comet-like objects were falling into the star.

As a follow-up to that discovery, Grady's team used Hubble's Space Telescope Imaging Spectrograph (STIS) and the Cosmic Origins Spectrograph (COS) in 2015 to conduct a spectrographic analysis in ultraviolet light, which allows Hubble to identify the signature of certain elements. Hubble made two observations, separated by six days.

Hubble detected silicon and carbon gas in the starlight. The gas was moving at about 360,000 miles per hour across the face of the star. The most likely explanation for the speedy gas is that Hubble is seeing material from comet-like objects that broke apart after streaking across the star's disk.

The gaseous debris from the disintegrating comets is vastly dispersed in front of the star. "As transiting features go, this vaporized material is easy to see because it contains very large structures," Grady said. "This is in marked contrast to trying to find a small, transiting exoplanet, where you're looking for tiny dips in the star's light."

Hubble gleaned this information because the HD 172555 debris disk surrounding the star is viewed close to edge-on through the disk, giving the telescope a clear view of comet activity.

Grady's team hopes to use STIS again in follow-up observations to look for oxygen and hydrogen, which would confirm the identity of the disintegrating objects as comets.

"Hubble shows that these star-grazers look and move like comets, but until we determine their composition, we cannot confirm they are comets," Grady said. "We need additional data to establish whether our star-grazers are icy like comets or more rocky like asteroids."

To perform this study, the team combined the Chandra X-ray data with very deep Hubble Space Telescope data over the same patch of sky. They studied X-ray emission from over 2,000 galaxies identified by Hubble that are located between about 12 and 13 billion light years from Earth.

Further work using Chandra and future X-ray observatories will be needed to provide a definite solution to the mystery of how supermassive black holes can quickly reach large masses. A larger sample of distant galaxies will come from observations with the James Webb Space Telescope, extending the study of X-ray emission from black holes out to even greater distances from Earth.
Deepest X-ray Image Ever Reveals Black Hole Treasure Trove

An unparalleled image from NASA’s Chandra X-ray Observatory gives astronomers the best look yet at the growth of black holes over billions of years beginning soon after the Big Bang. This is the deepest X-ray image ever obtained, collected with about 7 million seconds, or eleven and a half weeks, of Chandra observing time.

The image comes from what is known as the Chandra Deep Field-South. The central region of the image contains the highest concentration of supermassive black holes ever seen, equivalent to about 5,000 objects that would fit into the area on the sky covered by the full Moon and about a billion over the entire sky.

"With this one amazing picture, we can explore the earliest days of black holes in the Universe and see how they change over billions of years," said Niel Brandt of Pennsylvania State University in University Park, Pennsylvania, who led a team of astronomers studying the deep image.

About 70% of the objects in the new image are supermassive black holes, which may range in mass from about 100,000 to ten billion times the mass of the Sun. Gas falling towards these black holes becomes much hotter as it approaches the event horizon, or point of no return, producing bright X-ray emission.

"It can be very difficult to detect black holes in the early Universe because they are so far away and they only produce radiation if they're actively pulling in matter," said team member Bin Luo of Nanjing University in China. "But by staring long enough with Chandra, we can find and study large numbers of growing black holes, some of which appear not long after the Big Bang."

The new ultra-deep X-ray image allows scientists to explore ideas about how supermassive black holes grew about one to two billion years after the Big Bang. Using these data, the researchers showed that these black holes in the early Universe grow mostly in bursts, rather than via the slow accumulation of matter.

The scientists have also found hints that the seeds for supermassive black holes may be "heavy" with masses about 10,000 to 100,000 times that of the Sun, rather than light seeds with about 100 times the Sun’s mass. This addresses an important mystery in astrophysics about how these objects can

(Continued on page 10)
'Ghost particles' could improve understanding the universe

New measurements of neutrino oscillations, observed at the IceCube Neutrino Observatory at the South Pole, have shed light on outstanding questions regarding fundamental properties of neutrinos. These new measurements of neutrinos as they change from one type to another while they travel were presented at the American Physical Society Meeting in Washington. They could help fill key gaps in the Standard Model, the theory that describes the behavior of fundamental particles at every energy scale scientists have been able to measure.

"While the Standard Model is an accurate theory, it leaves gaping holes, like the nature of dark matter and how a universe filled with matter, rather than anti-matter, arose from the Big Bang. We don't know how to fill them yet," said Tyce DeYoung, MSU associate professor of physics and astronomy. "We're hoping that by measuring the properties of neutrinos, such as their masses and how they morph or oscillate from one into another, we may get some clues into these open questions."

Neutrinos are weird particles. Unlike other elementary particles that make up ordinary matter, such as electrons and quarks, neutrinos have no electric charge. They're also at least a million times lighter than any other particle known to science. In fact, their masses are so small scientists have not yet been able to measure them accurately.

With this in mind, DeYoung compares his work to a fishing trip, one in which scientists aren't quite sure of the best bait to use. "Fishing" through the ice of Antarctica, though, is yielding promising results and narrowing the search.

"As physicists, we hoped the Higgs boson would point us to the physics that lies beyond the Standard Model; unfortunately, our measurements of the Higgs haven't turned up many clues," DeYoung said. "So we hope we may find something by studying neutrinos. IceCube detects neutrinos with a wider range of energies and distances than other experiments, so we cast a wide net."

Energetic neutrinos produced by cosmic rays hitting Earth's atmosphere can be detected at the South Pole, using the Antarctic ice as a particle detector like no other on the planet. The IceCube data suggest that one species of neutrino may comprise exactly equal amounts of two neutrino "flavors."

"Neutrinos have a habit of changing, or oscillating, between three types, we call them "flavors," said Joshua Hignight, the MSU research associate who presented the new results at the meeting. "So, if one neutrino is a precisely equal mix of two flavors, it could be a surprising coincidence or there might be a deeper reason for it coming from the physics beyond the Standard Model."

These measurements are consistent from results from other experiments using neutrinos with lower energies, but whether this flavor mixture is exactly balanced remains under debate. The IceCube physicists will continue to refine their analysis and collect more data. Future data will enable these measurements to be made more precisely, DeYoung said.

IceCube is the world's largest neutrino detector, using a billion tons of the Antarctic ice cap beneath the U.S. Amundsen-Scott South Pole Station to observe neutrinos. It's operated by a collaboration of 300 physicists from 48 universities and national laboratories in 12 countries. Construction was made possible by support from the National Science Foundation and other international funding agencies.