

The View from the Piney Woods of East Texas

Kevin Krisciunas and Lifan Wang

George P. and Cynthia Woods Mitchell Institute for Fundamental Physics and Astronomy, Department of Physics and Astronomy, Texas A&M University, 4242 TAMU, College Station, TX 77843

The quest for the force that drives the accelerated expansion of the universe relies critically on the precision measurement of cosmological distances. Tremendous progresses have being made in the past two decades, and some more ambitious projects are been planned for the future. However, the fate of supernova cosmology is becoming less certain based on our limited knowledge of supernovae. We are still far from having a reliable theoretical model of these supernovae that can accurately predict their light curves and spectra. Systematic uncertainties of using thermonuclear supernovae (or Type Ia supernovae) as distance calibrators is blurring the error contours of cosmological parameters, to a degree that some veteran supernova experts now seriously doubt that any of the planned supernova cosmology experiments can significantly improve the current constraints deduced from the ESSENCE and SNLS projects, the latter are already systematic error limited and adding more supernovae with comparable data quality will not be statistically meaningfully. Reducing systematic errors is a serious challenge to supernova projects for the Dark Energy Survey (DES) and the Large Synoptic Survey Telescope (LSST) programs.

From 11-15 April 22 leading astronomers and physicists convened a workshop amongst the pines, meadows, and lakes of Cook's Branch Nature Conservancy, a 5660 acre estate near Montgomery, Texas, belonging to the family of George Mitchell. The goal of the conference was to look into the future and see what needs to be done today. Participants in the workshop included leading supernova observers as well as theorists such as Brian Schmidt (the 2011 Nobel Prize winner), Nicholas Suntzeff (co-founder of the High-Z Team), Mark Phillips (who discovered the Phillips Relation) and Reynald Pain (PI of the SNLS program).

Starting a century ago the Solvay conferences provided physicists with the opportunity to discuss

science without all the normal distractions of academic life. Almost every spring starting in 2007 string theorists from Cambridge Univ. and Texas A&M have had the opportunity to get together at the Mitchell's private ranch to discuss their research. A year ago two dozen astronomers met at Cook's Branch to talk about astronomical surveys of the next decade. Last June there was a galaxy formation workshop. In mid-April of 2012 another group met to discuss "Supernova cosmology and looking into the future."

Some people in the astronomical community have the present sentiment: "Oh, supernovae – they're so *last decade!*" The observational evidence for a positive cosmological constant was at the limits of what we could measure 14 years ago, but now, after the analysis of data from the Wilkinson Microwave Anisotropy Probe, astronomers almost universally acknowledged that the geometry of the universe is very, very close to being flat, and the matter density of the universe is less than 30 percent of that necessary to halt the expansion of the universe. The result is that more than 70 percent of the energy budget of the universe is in Dark Energy.

Ah, but what next? The James Webb Space Telescope and other potential space missions will not be returning data to us for years. What can we do in the meantime? Ariel Goobar showed that we could monitor foreground galaxy clusters like Abell 1689 to find supernovae at redshift 1.7 (look-back time 9.85 billion years) which could be up to 3 magnitudes brighter due to lensing magnification by the foreground cluster.

Calibration continues to be an issue. We can obtain luminosity distances to ± 7 percent, but to achieve ± 1 percent is beyond our capabilities. This is necessary to reach the next plateau of observational cosmology using fluxes. What do we need? How about a space platform standard flux source? We also need portable tunable laser systems or monochromators to scan our photometric filters *in situ*, with all the telescope reflections and transmissions automatically measured together. Chris Stubbs (Harvard) and Jean-Phillipe Rheault (Texas A&M) have shown the way for the future of such calibration.

As surveys grow we expect to discover more supernova sub-types. Models need to correlate what we observe with progenitors. Most researchers agree that a Type Ia supernova is the explosion of two merging white dwarf stars, or the explosion of one carbon-oxygen white dwarf which approaches 1.4 solar masses due to mass transfer from a much larger companion (a main sequence star or giant star). Models by Peter Hoefflich, Eddie Baron, and Alexei Khokhlov give us a handle on the mass of the progenitor star that died as an exploding white dwarf, and we also get a handle on the central density of that white dwarf. These models were motivated by the excellent data obtained by the Carnegie Supernova Project at Las Campanas, Chile.

At maximum light a Type Ia supernovae only puts out 3.6 percent of its light in three standard near-infrared bands at 1.25, 1.65, and 2.2 microns. Everything about the explosion is non-linear, *but* the amount of light given off in those three near-IR bands is essentially constant at maximum light, no matter what the yield of ^{56}Ni (which powers the light curve). Why? No one can explain this. From an observer's standpoint it does not matter much; we are just happy we can use these objects as nearly perfect standard candles. This leads to very accurate distances, as any effects of interstellar dust are minimal in the near-IR, or easily corrected.

We do not know for sure if the progenitors of Type Ia supernovae are the same at all redshifts. Spectroscopic evidence is a bit ragged, but we need better spectra, particularly rest-frame ultraviolet spectra, to test this. Texas A&M postdoc Peter Brown refers to this as, "the peril and the promise." One aspect of the peril is that *U*-band light curves of a Type Ia supernova obtained with different telescopes can show systematic differences of several tenths of a magnitude, even though they were reduced with standard stars on the same photometric system. As shown by Texas A&M astronomer Kevin Krisciunas, the promise is that spectroscopically-determined corrections to such photometry can reduce these systematic errors to a level smaller than the random errors of the data. One accounts for differences in the effective filters used in difference cameras.

Mitchell, who made his fortune in natural gas exploration and real estate development, graduated with a degree in petroleum engineering in 1940 from Texas A&M University, and now, in his twilight years, has donated tens of millions of dollars to his *alma mater* and has funded the casting and polishing of the first two mirrors of the Giant Magellan Telescope. Owing to his support, the Texas A&M Dept. of Physics and Astronomy now has seven faculty astronomers, four postdocs, and a dozen grad students working on astronomy research.

George Mitchell and his “right hand man,” daughter Sheridan Lorenz, would like to see two astronomy workshops per year at Cook’s Branch for the indefinite future. Away from the bustle of city life, one can rise at dawn to view the red cockaded woodpecker (*Picoides borealis*). Less endangered are the cubit-length bass in the lake next to the main lodge. One such fish was hooked by Chris Stubbs. In such a peaceful location scientists can calmly assess the state of their field and think about should be tackled next, and how that should be done.