Special Contribution

Nobel Minds Expand Our Universe

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There had been considerable speculation that he would eventually receive the world's most famous award, yet I was still pleasantly surprised on the day Saul Perlmutter won the 2011 Nobel Prize in Physics along with Brian Schmidt and Adam Riess for the discovery of the accelerating expansion of the universe. I served on Saul's team as an undergraduate (and later "post-baccalaureate") from 1997 and made a small contribution to the prize-winning paper. Saul generously invited the whole team to join in the festivities, so last December I boarded a plane bound for Stockholm.

My connection to this Nobel Prize winning research began when I was at Berkeley looking for some research experience to fill out my future graduate school applications. Not sure of what to do, I sent out a blind email solicitation. Ok, I spammed the physics department. Luckily, I got one reply from "George" who didn't have a job for me but knew someone who might. Saul Perlmutter was leading a project that involved supernovae, which seemed a good match given my astrophysics major. This was one of the great advantages of studying at UC Berkeley; there was plenty of interesting research being conducted, and there were great advisers to point astray students in the right direction (George Smoot went on to win the 2006 Nobel Prize in Physics).

Saul's team was using distant Type Ia supernovae to derive the matter density of the universe and the deceleration parameter, which was originally intended to express how quickly the expansion of the universe was slowing down due to the confining pull of gravity. As the Nobel Prize was awarded for the acceleration in the expansion of the universe, we now know that the value of this deceleration parameter is negative. But this was not clear at the time as reflected in this unfortunate name.

The key to using Type Ia supernovae as cosmological probes comes from empirical evidence that different Type Ia supernovae all have about the same peak luminosity. This may be attributed theoretically to physical laws that limit how much mass white dwarfs, the dying embers of stars similar to our Sun, can steal from a companion and remain stable. There is still debate about the exact nature of these progenitor systems, but if one considers a white dwarf star near its critical mass limit as a necessary ingredient, then the conformity in Type Ia supernovae can simply be explained by the similar quantities and distributions of fuel in the explosions. Turning these stellar bombs into rulers to measure great distances is then straightforward.

As with any source of light, the brightness of a supernova appears to decrease with the distance to the observer squared. Since we know the luminosity of Type Ia, we also know how distant they are to good accuracy (about 5% with careful corrections), and since they are quite bright, we can see them even when they are extremely far away. The light from the most distant Type Ia supernovae discovered came from so far away that it takes about 10 billion years to reach earth. The universe has expanded greatly since these stars exploded, and this effects the photons on their journey to earth as well so that short wavelength blue light get stretched into red. The extent of this "redshift" conveys the accumulated effects of this expansion since the light escaped from these exploding stars. By measuring the redshifts to Type Ia supernovae over a range of distances, Saul hoped to map out

The Supernova Cosmology Project members in Stockholm during Nobel Week. Back row: Ivan Small, Sebastian Fabbro, Greg Aldering, Robert Quimby, Brad Schaefer, Rob Knop, Renald Pain, Carl Pennypacker, Shane Burns, Richard Muller, Ariel Goobar, Peter Nugent. Front row: Alex Kim, Pilar Ruiz-Lapuente, Andy Fruchter, Nelson Nunes (middle), Richard Ellis, Julia Lee, Susana Deustua, Saul Perlmutter, Warrick Couch, Heidi Newberg, Sylvia Gabi, Chris Lidman, Don Groom.

the universe's expansion history and determine just how much gravity was slowing down the expansion of the universe. At least that was the original plan.

Saul invented a novel technique to discover distant Type Ia supernovae in batches, on demand. A galaxy such as our own Milky Way has, on average, just one Type Ia supernova every 200 years. It is therefore impractical to discover supernovae in any particular galaxy within the lifetime of a typical research grant. However, if you look in any direction at a patch of sky roughly the size of the full moon, there are thousands of distant galaxies churning out Type Ia supernovae. Take a deep enough exposure of a few such patches, and when you revisit the fields with your telescope a month later, there will be a dozen new Type Ia supernovae waiting to be found. As Saul explained during his Nobel Lecture in the magnificent Aula Manga lecture hall of Stockholm University, the tough part was convincing the telescope allocation committees that this would work and to schedule the observing runs as needed. It was not enough for Saul to invent the strategy to find cosmologically interesting supernovae; he needed the tenacity to see it carried out despite formidable opposition.

The Lectures are one of the first events in what is known as Nobel Week. It was also the moment that I began to realize that this was real – Brian, Adam, and Saul had really won the Nobel prize, and there they were on stage regaling a packed auditorium with the tale of their discovery. Brian recounted how he had read one of the first telegrams put out by Saul's team, the Supernova Cosmology Project, to announce the successful discovery of a batch of high redshift supernovae and decided to start a competing team leveraging his group's expertise using Type Ia supernovae as distance indicators. Brian invited Adam to join, and the High-z Search Team was born. As you might imagine, the competition for resources and to publish first fomented a certain amount of animosity in the early days, but this has faded away over the years.

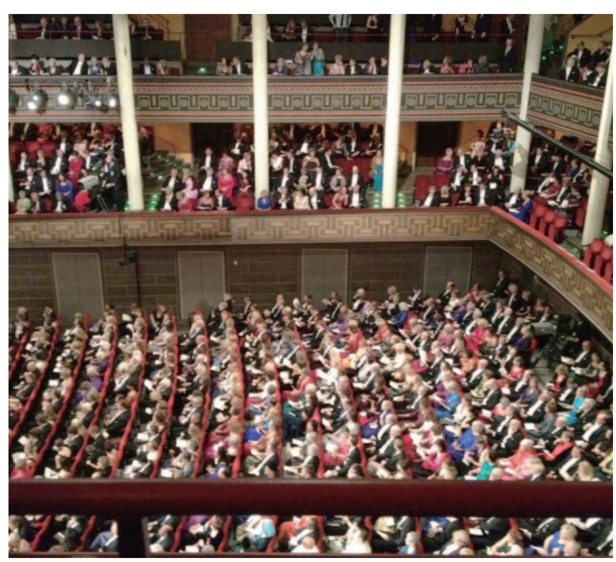
The highlight of Nobel Week is of course the award ceremony, which is followed by a banquet, dancing, and then more dancing. This all begins the anniversary of Alfred Nobel's birth, December 10, with the celebration running well past midnight. The laureates are each given complimentary tickets to share with their families and collaborators, but the standard allocation is not enough to accommodate all the co-authors on such modern, highly collaborative experiments. An equal number is given to each awardee, so the High-z Team started off with twice the number of seats as the Supernova Cosmology Project, which evoked some grumbling amongst my team, echoes of the former rivalry. Saul pleaded on behalf of his collaborators, and in the end all of the team members in Stockholm received tickets to the ceremony (mine came just hours before the start of the show).

Dressed in our formal costumes – white tie and tails for the men and evening gowns for the women – we observed from the balcony as the drums rolled and the King, Queen, and Crown Princess of Sweden entered the theater. The orchestra played Mozart as the winners of the physics, chemistry, medicine economics, and literature prizes marched in. This was not the most common of venues for an astronomer like myself who is more familiar with jeans and tee-shirts than tuxedos and waist coats, and the fact that much of the ceremony is done in Swedish did not help me to feel at home either. But it was absolutely amazing, nonetheless, to see Saul honored on stage at this most prestigious ceremony.

Saul was the first laureate to be awarded his prize, which like everything else that night was a tightly choreographed process constrained by customs far older than the prize itself. For the record, the proper procedure for receiving your Nobel Prize is: 1) stand when called upon and walk to the center of the stage, 2) receive the boxes with your diploma and medal from the King with two hands, 3) shake the King's hand, 4) step back and bow to the King, 5) turn 45 degrees to your left and bow to the Nobel Academy on stage, and 6) turn to face the audience, bow, and bask in your ovation. When the applause die down, you may return to your seat, but don't open boxes! They will be collected after the ceremony and the contents displayed for 2 days before they are returned to you for good.

Saul appeared slightly nervous as he walked to the King, and it was reassuring to see that he and the other laureates retained their humility in spite of the pampering heaped on them since the announcement of their honor. He executed the next two steps with precision, but nearly erred on the fourth step. After taking the customary two steps back, Saul began to turn ever so slightly without bowing to the King. The audience let out a collective gasp. Saul corrected himself and bowed to the King appropriately, much to the relief of those in attendance. The near transgression lasted perhaps one second, but it served to intensify then break the tension in the room.

The ceremony was followed by the



The Nobel Prize Ceremony in the Stockholm Concert Hall.

Nobel Banquet, which was held in the Stockholm City Hall. Despite the 1300 seats in the main hall, which is a voluminous room decorated to give the feeling of being outdoors, tickets were again in short supply for the two teams, and I joined the overflow in a separate room (the actual dining hall in the basement). The adjacent room held the relatives of Alfred Nobel, and we all had the same three-course meal served to the laureates and royalty, complete with a pyrotechnic dessert. After coffee and cognac, two of the six beverages served through the meal, we were escorted upstairs to join the party. I managed to fight through the crowds to congratulate Saul, and he humored me when I asked for a picture, as did so many others that night. As if this all weren't enough, there was a final celebration, the Nobel Night Cap, thrown by University of Stockholm students. The Laureates still had energy to chat and pose for pictures well past 3 am when we said our goodnights.

I was invited to participate in this fantastic week of celebration for providing a small but important role in the discovery. I helped fit models to the data to find the cosmological parameters. Saul has described the realization of his discovery not as a single moment, but rather as a long "ah—ha" process. My contribution came near the end of this when it started to become clear that the supernovae discovered actually appeared a little fainter than we had expected given their redshifts. In other words, it seemed that the universe had expanded more than expected since these distant supernovae exploded. Saul asked me to help determine if there was evidence that the expansion of the universe was not slowing down at all, but rather accelerating. He rushed to my office on the day the results came in, and I reported that with greater than 99% confidence, the expansion history of the universe could not be fit by the gentle attraction of gravity alone. True to his meticulous style, Saul requested double, triple, and quadruple checks, but the results held: a mysterious force is pulling the universe apart.

The 2011 Nobel Prize laureate, Saul Perlmutter, with the author after the banquet.

After participating in what has become a Nobel Prize winning experiment, I attended graduate school where I continued to study supernovae. This time instead of looking across the universe, I created my own modest search to locate the closest Type Ia supernovae I could find. I began to study supernovae themselves to help reveal exactly what they are to help perfect the calibration of their peak magnitudes and turn them into even better distance indicators, which will be useful in addressing the obvious question remaining after the champagne was finished, "what is the nature of this Dark Energy accelerating the universe?" Amazingly, the first empirical evidence that Type Ia supernova are truly the explosions of white dwarf stars was not obtained until late 2011 by the Palomar Transient Factory, which I have contributed to as a postdoc. Questions about the nature of the companion are just beginning to be addressed.

During my search for ordinary Type Ia explosions, I uncovered the extraordinary supernovae with peak magnitudes and energetics ten times greater than ever seen before. Much like their lower luminosity cousins, these superluminous supernovae may serve as probes of the distant universe and help reveal its beginnings. Whether the results will similarly defy expectations remains to be seen.