Townes group activities from 1983-2000: Personal Recollections of William Danchi
April 2, 2015.

1983-1985:

I arrived in Berkeley in October 1983 as a post-doc, and my appointment was at the Space Sciences Laboratory (SSL). During that time the group was very large, with multiple activities led by Charlie himself and also by Senior Fellows such as John Lacy, Dan Jaffe, and Al Betz at the top of the hill at Space Sciences. Another significant contingent of the Townes group was housed in Birge Hall on campus, led by Reinhard Genzel when he was an Assistant Professor in the Physics Department. Although the group encompassed two separate locations, it functioned as one large group. Either we rode with Charlie up and down the hill, or (if we were concerned about our safety!) we took the bus.

The major activities in which Charlie was most focused at that time included:

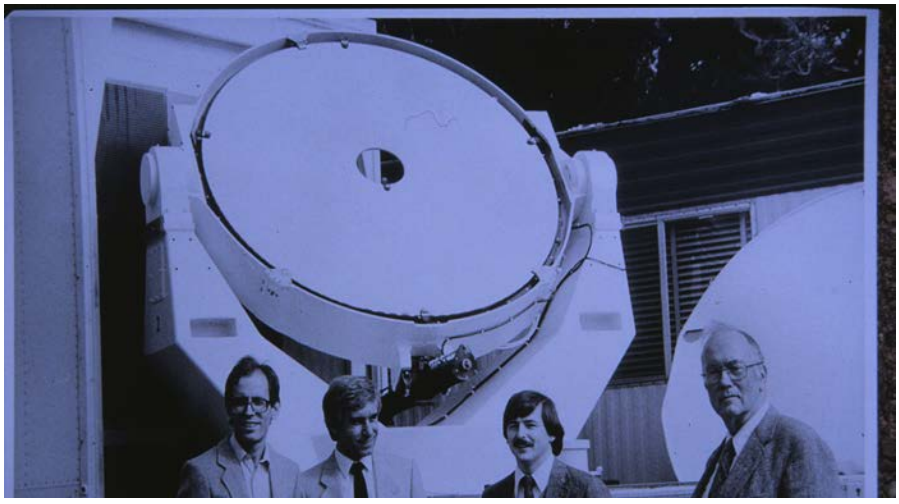
- The *Airborne Astronomy Program* with the Kuiper Airborne Observatory sponsored by NASA, using the Fabry-Perot spectrometer originally built by John Storey, with significant detector upgrades being done by Gordon Stacey:

Reinhard was also heavily involved in this project and was most likely a co-PI on the project, but you'll have to ask him. Other post-docs who were involved in the project included Mike Crawford and Jurgen Stutzki, who came later. As the 1980s wore on, John Lacy and Dan Jaffe left for jobs at the University of Texas in Austin, and Reinhard Genzel became a Director at the Max Planck Institute in Garching. Charlie continued to work with Reinhard and Gordon Stacey on the Far-infrared Airborne Astronomy Program until the Kuiper Airborne Observatory itself was decommissioned.

- The *Mid-infrared Imaging Project* that was the thesis of Eric Bloemhof: Charlie had gotten an early one-dimensional detector array from one of the companies doing military research. I was heavily involved with this project as well. We obtained the first diffraction-limited images at 10 microns from a large telescope (Canada France Hawaii Telescope [CHFT] and the Infrared Telescope Facility [IRTF]). Eric and I did most of the observing but Charlie also went observing with us when his schedule allowed.

The new *Infrared Spatial Interferometer (ISI)* was launched shortly before I arrived at the Space Sciences Laboratory, and the largest activity in the Townes group at that time: I was the first scientist hired full-time to work on it, although some initial work had been done by some of the graduate students at the time, such as Eric Bloemhof, John Lugten, and a few others, who had helped part-time while they were doing their thesis research on other topics. The project was funded by a large DARPA (Defense Projects Research Agency) grant that was administered through the Navy. DARPA had just funded two programs to initiate modern stellar interferometry in the United States. One was our program in the mid-infrared, and the other was the Mark III Interferometer at Mt. Wilson, led by Ken Johnston and Mike Shao, that operated at visible wavelengths.

Our group at SSL expanded considerably during that time. When I was hired, Ed Sutton, a former grad student, was brought back to SSL early in 1984 and he became a Senior Fellow as well. We also hired Manfred Bester around 1985, after he had finished his Ph.D. thesis in Germany with Gerhard Winnewisser.



We had a large team of engineers who were from SSL and the Lawrence Berkeley Laboratories (LBL)

and were able to obtain high-bay space at LBL in order to build the telescopes subsystems into the trailers. So now we were spread over three locations, with a lot of driving up and down the hill. All told we had about 20 people working on the project led by Charlie, Manfred, Ed and me. We had considerable help from Al Betz in particular, who was working on a far-infrared heterodyne spectrometer for the Kuiper Airborne Observatory at that time, with graduate students Tony Mannucci, Dave Goldhaber, and Jonas Zmuidzinas.

1986-1990:

From 1986 to about 1988, there was a lot happening in the group. Charlie was primarily focused on the Infrared Spatial Interferometer (ISI) all during that time period. We completed testing at LBL in the fall

of 1987, and we shipped (drove) the trailers to Mt. Wilson just before winter set in around December 1987. The journey from Berkeley to Mt. Wilson took two days and during the drive Charlie was in the semi-tractor pulling the trailer containing one of the telescopes and I had the honor to be in the other semi-tractor pulling the

trailer containing the other telescope. Dennis Sietz and Walt Fitelson drove a large U-Haul truck containing many of the auxiliary subsystems and spare electronics. I recall early observing runs with lots of snow and frustration at Mt.Wilson. First fringes were obtained with the ISI in summer of 1988.

In 1986 Charlie paid me a great compliment, which meant a lot to me at that time, and continues to this day. I had been working on the ISI for about three years. He was invited to a conference to give a talk about the ISI. He wanted me to give the talk instead and discussed this with the organizers. They told him that they didn't know who I was and didn't want me to give the talk. Charlie was angry with them about this and he told me that "Bill Danchi knows as much about interferometry as anybody and if they won't let him give the talk then I won't attend that conference." It meant a lot to me that he stuck up for me and in fact he boycotted that conference as he said he would.

We had several foreign visitors to the group during that time period, primarily from France. Jean Gay and his son Jean-Philippe both visited but on separate occasions and they contributed to the optical design. Around 1986 or so, we were very fortunate to have Bernard Sadoulet, who made significant contributions to the electronics for the ISI, in particular the laser phase lock, which was very important to the success of the project. Also we had help from John Storey, who visited us over several years during his Australian summer vacation.

My personal focus was on the optics and the detection system including the CO_2 lasers and the detectors and RF system, although I worked on almost every aspect of the project over the years, including shaking the mounts with Walt Fitelson to look for the mechanical resonances in them. By shaking the mounts I don't mean literally shaking them. What we did was to apply a sinusoidal input voltage to the servo motors that drove the mounts in altitude and azimuth to track the stars. The frequency was increased from a low frequency, like 1 Hz, to a high frequency, like 100 Hz. We measured the response of the mounts to the sine wave input, and we looked for mechanical resonances in which the

mounts did indeed strongly shake, to see if they were at the frequencies and amplitudes that were expected. This was of importance to us because we wanted to have a very fast and precise tracking system so we could track not only stars, which moved fairly slowly during the night, but also satellites in fairly low orbits, which moved very fast. Charlie had a keen interest in this aspect of the system as we wanted fast precise tracking due in part to our Navy sponsorship.

During the extended building period for the ISI, Charlie was kind to me in many ways. One was that he gave me the Fröhlich Fellowship, which paid for most of my salary for four years, from 1986 to 1990. Another was that he allowed Ed Sutton and me to pursue our interest in developing a 345 GHz Superconductor-Insulator-Superconductor (SIS) mixer receiver system for very-high-spectral resolution studies of molecules in the interstellar medium. Ed and I wrote a proposal for the US Army, which funded advanced research at that time. Our proposal was successful and we succeeded in building the first operational 345 GHz receiver. Such receivers were new and they could achieve sensitivity levels close to those imposed by quantum mechanics. We observed at the Caltech Submillimeter Observatory and the James Clerk Maxwell Telescope, and we published early molecular line surveys of Orion, Sgr B2, and other objects. This meant a lot to me because it is hard to spend so much of your early career building such a complex system, which did not allow a lot of opportunities to publish. Working with Ed on the SIS mixers and with Eric on the array camera allowed me to publish, while there were very few opportunities to publish the mostly technical work we did on the ISI during that period. Ed and I continued to collaborate on SIS mixer work with a graduate student, Paul Jaminet, who helped build the 492 GHz receiver that was the successor the previous one.

From 1988 to 1990 we made our first observations with the ISI, which was now operational, but we realized that we needed to make a number of improvements to the system to improve the sensitivity and functionality of the system. However we did start publishing our first science results. I was the first author on our first *Astrophysical Journal Letter* paper in 1990, and I remember the excitement in the community at an SPIE meeting when we started announcing that the ISI was a functioning stellar interferometer. Around that time Al Betz left for the University of Colorado in Boulder, and Ed Sutton left for the University of Illinois at Urbana-Champaign.

We continued to have significant visitors. One such person is Bruno Lopez from the University of Nice Sophia-Antipolis who visited us and helped analyze some of the early data from the interferometer. He used some of the data for his Ph.D. thesis, in which he developed one of the very first Monte Carlo

radiative transfer codes. Later he visited again and he and I wrote an important paper on asymmetries in the dust shell around Mira Ceti using his code to help us interpret the data we obtained with the ISI. We had excellent post-docs as well, namely Lincoln Greenhill and Cuno Degiacomi. Lincoln was particularly helpful with the data analysis, bringing us a very useful radiative transfer code that we used extensively for a number of our papers. Also Lincoln and I combined results from the ISI with those from Very Long Baseline Interferometry to determine the relative location of molecular masers to the dust being created by the cool outflows from the stars. This was important to theorists who were developing models of the underlying physics of the masers. Cuno was a really gifted experimental physicist who made important contributions to some of the early upgrades to the system.

1990-2000:

Around 1990 or so, I was promoted to be a Senior Fellow at Space Sciences, and at that point in time Charlie and I managed the group as a team. Each of us did fundraising. He was able to obtain funding from Department of Defense (DoD) sources such as the Navy, and I was able to obtain funding from the National Science Foundation (NSF). I focused most of my effort on funding upgrades to the ISI and to find ways to pay for the observing program. I had a fairly large grant to complete one set of upgrades to the telescope, namely guiding cameras, tip-tilt corrections, and improvements to the detection system. Also, I was able to obtain a grant to help support observations at Mt. Wilson, the analysis of the data, and publications. We were fortunate to have several excellent graduate students and post-docs at that time, including Everett Lipman, who was involved in many upgrades, and also John Monnier, who built a spectrometer so we could differentiate between molecules and dust in the outflows of the late-type mass losing stars that were the focus of the program. We also hired Peter Tuthill as a post-doc, who had just finished his Ph.D. thesis in Cambridge with John Baldwin and Chris Haniff.

At the time I was also interested in building a third telescope for the ISI. I was the PI of a large proposal to build this telescope, and Charlie was the co-PI. We started the third telescope project around 1994-1995, and got most of the way through it, until about 1997 or so, when we realized we did not have enough funding to complete the project, that is, aside from the telescope itself. During a difficult year between grants, I was able to write another proposal, which was successful and allowed us to complete the project. During that time period we were busy with observing and with developing the third telescope and the subsystems necessary for the three telescopes to work together. Manfred Bester was the project scientist for much of that time period, until he decided to work with Bob Lin on the High Energy Solar Spectroscopic Imager (HESSI) project, for which he was in charge of building the ground station.

Manfred did a terrific job on the ground station, and not only was it important for HESSI (now called RHESSI), but also for other projects that came afterward.

I remember when I was promoted, Charlie took me aside to talk me about my new role as a PI and fundraiser, saying "Bill, it is time that you learn the business aspects of our business," meaning that I had to learn how to understand the ledgers provided to us by the accounting system that we used to keep track of our monthly expenditures. We took some classes on how to read the ledgers that the university provided, and indeed it was helpful. However, due to the time pressures we had in terms of upgrading the ISI, building the third telescope, and all the other activities, eventually we realized we needed a person to do this aspect of our business, so we hired Trish Dobson to maintain our books, starting in the late 1990s.

During that time, I became interested in work on the Keck Telescope, which was just becoming operational in the early 1990s. I was interested in applying aperture masking interferometry techniques that Peter had used on the Herschel Telescope in the Canary Islands at optical wavelengths to the near-infrared wavelengths that were accessible with the NIRC instrument on the Keck Telescope. So Peter and I, with help from Chris Haniff, got a program started, and to our surprise, we were allowed to install our aperture masks in front of the secondary mirror. John Monnier joined the team during the time when he was waiting for his spectrometer to be completed and this work became part of his thesis research. I was the Principal Investigator for this work, as I had access to the Keck Telescope, and the work was funded through my NSF grants at that time. Charlie was very supportive of this work, and after I left Berkeley, we were able to continue the work until about 2004, with his access to the Keck Telescope with him as the PI.

During this time period, not only did we have the aperture masking work, the upgrades to the existing two telescopes, and the construction of the third telescope, but we also were getting involved in another aspect

of the Keck Telescope. The project was the revival of the Long Wavelength Spectrometer (LWS) and the Long Wavelength Infrared Camera (LWIRC). I was asked by SSL Director Chris McKee to take on this additional work. In doing so I had to build another team to work on this project. I was fortunate to be able to hire Ed Wishnow, who had been working at the Lawrence Livermore Laboratory, to be the Project Scientist for this additional project that I was to lead. Ed helped put together the rest of the team and he was instrumental in completing the project. LWIRC passed all of its reviews and was shipped to the Keck Observatory, but due to budgetary and personnel limitations at the observatory, it was never integrated and used. The revival of LWS was successful and our team did receive credit for substantial contributions to it, and we did have observing time awarded for our efforts.

The late 1990s was a time of change again for the group. Everett Lipman and John Monnier received their PhDs around 1998 or 1999, and Peter Tuthill was awarded a prestigious fellowship at the University of Sydney in Australia, his home country. I was pursued by NASA Goddard Space Flight Center, and around December 1999, I took a senior position at the Center. We were still finishing the 3rd telescope and associated systems at UC Berkeley, so Charlie and I negotiated a long period in which I was still resident in Berkeley most of the time. Goddard paid my salary and Charlie paid for the travel, out of the grants that I had at the time from the NSF. The reason for this is that once I resigned from Berkeley I turned over responsibility for those grants to Charlie, as the rules between the NSF and NASA did not allow me to continue at NASA as the PI of those grants. We had an excellent graduate student, Jon Weiner, who worked with me on the lasers and detection system.

2000 and beyond:

Charlie and I continued to work together with the ISI, aperture masking with the Keck Telescope, and the Keck Interferometer until the mid-2000s. Also, I worked with Ed Wishnow reviving some old data analysis software. After that I saw Charlie from time to time at conferences and in Berkeley when I was

traveling through the Bay Area. . I remember giving a talk about some of the work I had been doing developing a space interferometer for exoplanet science and my other activities.

The last time I saw Charlie and Frances was in the late 2000s when I spent some time visiting at SSL. They had just moved from their house in Berkeley to their retirement home near Lake Merritt in Oakland. During that visit, I drove Charlie around since he was no longer able to drive. I recall that he spoke of the invention of the maser and laser. It bothered him that those inventions, which were considered so radical at that time, were now considered "obvious." I don't think they are actually so obvious, and his greatness with those inventions was that he was able to combine knowledge of stimulated emission, feedback from the cavity, and population inversion due to the existence of metastable states of molecules, into a useful device. These were inventions that combined knowledge of multiple disciplines and were syntheses of ideas and techniques.

I was in France at the time of his death working with Bruno Lopez on the Multi-AperTure mid-Infrared SpectroScopic Experiment (MATISSE) instrument, a second generation mid-infrared instrument for the Very Large Telescope Interferometer (VLTI), and I gave a talk on the work we were doing with the Large Binocular Telescope Inteferometer (LBTI). The work that we started in Berkeley with the ISI and the relationships formed between members of the group continues to this day. However, for a long time the ISI was truly unique — from 1988 to the early 2000s — until the first mid-infrared instrument for the VLTI came online, the MID-ir Interferometer (MIDI) instrument. I am very proud of the fact that we were so far ahead of other groups for so long.

Given the time limitation I have had to write this brief memoir, I have likely missed some the names of some people who worked in the group, and there are certainly more stories to tell about that time period and the work we did together. I worked closely with Charlie for about 17 years, and we collaborated for another few years after that.

Over the years my relationship with Charlie evolved. He was my teacher, mentor, colleague, and friend. I miss his intelligence, his warmth, his humor, and his wisdom … as I am sure many in the audience do as well.