Tristan Hubsch

Dr. Tristan Hubsch is a famous mathematician and physicist. He is currently a professor at Howard University. He works on string theory and is known for his work on the superstring theory and Calabi-Yau spaces.

As Long as It Has Substance

It doesn't matter what it's called, math or physics—as long as it has substance.

S.-T. Yau

It is an immense pleasure (but even more so a guilty one) to find myself congratulating Prof. Shing-Tung Yau on his seventh decade of unquenched curiosity and wide-ranging interests, on his unparalleled perspective and unabating ardor, on his enduring endeavors and—*of course*—awe-inspiring achievements. The two short years I have had the privilege to be his postdoc ('90–92, at Harvard University, with a 3-month visit at the National Tsing-Hua University at Hsinchu, Taiwan) have left an indelible impression on me: an awesome inspiration, to a rough and remote approximation of which I can still only aspire.

In 1988, Prof. Yau came to visit the '88 String Theory Conference at the University of Maryland, by which time I had been Philip Candelas' postdoc, having contributed to the first lists of complete intersection Calabi-Yau (CICY) 3-folds in products of projective spaces, and having co-discovered with Paul Green that all of those connect in the manner prophesied by Miles Reid's conjecture. In this (to my mind) pivotal point in string theory, Prof. Yau showed up and naturally all participants flocked, asking all kinds of questions about these exciting (for physicists) new beasts: compact, complex, Kähler and Ricci-flat empty spacetime geometries. I cannot find the right words to specify the syzygy of those first impressions, but right then and there, I knew where I simply had to go for my next postdoc; two years later, I succeeded[1] Brian Greene as Prof. Yau's "physics postdoc".

[1] Those were some impressive shoes to fill… no pressure…

Wide-Ranging Interests

During my '90–92 stay at Harvard, I shared the office next to Prof. Yau's with his computer science postodoc, Ya-Yan Lu—and had my first glimpse of Prof. Yau's wide-ranging interests and endeavors. I remember my own mild amusement at his intense interest in learning about the computer-aided methods in the study of eigenvalue distributions. At the time, I did not see the relevance of that pursuit (but was at times glad that it was Ya-Yan's and not my turn to be questioned about progress.) Twenty-seven years later, computer-aided research just discovered that there exists a "mole ($\sim 10^{23}$) of Standard Models" among just CICY-compactified superstrings, and $\sim 10^{700}$ times as many amongst toric embeddings, at once opening up the "holy grail" of string theory phenomenology to statistical and computer-aided methods—and in fact necessitating it. The '93 Yau-Lu paper on "Reducing the Symmetric Matrix Eigenvalue Problem…" is still being vigorously cited, and I'm sure will continue to be of lasting relevance—now perhaps even more so as it finds its applications in searching through string theory compactifications.

Back in the early 1990s, it did not surprise me that Prof. Yau was becoming involved in scientific publishing: over our frequent free-wheeling lunch-discussions, we have exchanged many thoughts on pros and cons of the scientific publication scene at the time, and it was clear to me that he had a better vision. A quarter of a century later, International Press (founded in '92) clearly validates that far-reaching vision. It therefore did not really surprise me to learn, twenty years later at the August 2008 conference "Geometric Analysis: Present and Future", that he had become involved with digital imaging and image-mapping. It reminded me that back in '91 or so, thinking out loud, he told me of his vision of AI-powered medical condition triage, where a person could walk up to an ATM-style access point, have a preliminary diagnosis of their health symptoms, and be directed to the most appropriate physicians and

health-care providers. While this may seem a bit of science-fiction, I'm certain that this one of Prof. Yau's many visions will become reality, and possibly quite soon.

Prof. Yau's students can easily attest to his fascinating prowess in mathematics, both as a researcher and as a mentor, but I hope these few thoughts hint at some complementing aspects that may not be as obvious to all.

Perspective and Ardor

In my exchanges with Prof. Yau, and especially our collaborative efforts, I was always impressed and humbled by an exquisite dual quality: Being able to see both the big picture and the scope and extent of the details involved, even when one is mired in pesky technical and unresolved issues of the topic at hand. In our earliest interactions when I started as his postdoc (Fall of '90), Prof. Yau kept peppering me with questions about supersymmetry, field theories and string theory. Knowing of the lack of proper rigorous definition of the path-integral methods, I was at first hesitant to mention it, but have soon discovered that Prof. Yau (and also Prof. Raoul Bott, as I soon found out), saw clearly the potentials of this wondrous concept and how and where its applications might be of benefit—unconcerned by the haziness of the scaffolding as presented by physicists. That's the first time I have heard of "general nonsense",—which for me in turn is still a very hazy concept, but which seems to have provided him with a guidance not unlike as what I'd best describe as "laser-precise intuition." Only someone with a perspective as powerful as Prof. Yau's could, back then, not only see the goals that such a vehicle may reach, but also the multiple connected details of the roadmap, and zoom in on the simplest possible route, as well as note the roadblocks to avoid: a Google-map of sorts, in mathematics and mathematical physics!

His co-organizing (with Prof. Isadore Singer) of the May 1991 MSRI Mirror Symmetry Workshop was at once mold-breaking and prescient: The foresight to indulge physicists' experimental mathematics has led to the mirror symmetry boom of boons, and is a gift that keeps giving to both disciplines. At the time, none of the other mathematicians in the workshop were "buying it", and especially because the presented report by Geir Ellingsrud and Stein A. Strømme (using what to physicists was unintelligibly high-brow mathematics of Hilbert schemes) disagreed with one of the physics numerical results. Even so, I recall Prof. Yau's careful optimism, that the disagreement *will* get sorted out.—Which it did, and very soon, once the mathematicians corrected their numerical computation, and mirror symmetry ushered in a wave of developments in both mathematics and physics, which continue to permeate the two fields ever deeper and ever further.

Prof. Yau has also contributed directly to the topic, such as the so-called SYZ-formulation (Andrew Strominger, S.-T. Yau and Eric Zaslow, '96) of mirror symmetry, which has over the past two decades outgrown its original setting, and now provides one of the key approaches to the phenomenon and its manifold consequences. Nevertheless, I should prefer to highlight Prof. Yau's original impetus and perspective: he has seen—and continues to see—at once both farther and sharper than most.

Achievements and Legacy

I was flattered by the invitation to participate in the August 2008 conference celebrating Prof. Yau's 60th birthday, but fully realized the gravitas of the occasion only as the conference began: I had no idea of the extent of his academical progeny. (Physicists do not have a genealogy database, so consulting genealogy.math.ndsu.nodak.edu never occurred to me.) The realization slowly set in, and in ways that are beyond impressive and awesomely inspiring: The weeklong series of eight hard-science presentations every day, in diverse fields and on various topics, presented mostly by Prof. Yau's academic descendants, postdocs and collaborators—to an auditorium full to the rafters—it was a clear indication that this was but the tip of the proverbial mountain!

At this conference, I also met Steve Nadis, Prof. Yau's co-author on the forthcoming book *The Shape of Inner Space*. At Prof. Yau's behest, he was interviewing many of the attendees regarding the developments in the research on Calabi-Yau manifolds and mirror symmetry. Over the next several months and numerous interactions, I came to realize the systematic depth, the attention to detail, fair credit to all involved, and accurate presentation of the topic and its history—qualities that are sometimes woefully absent in the literature. Calabi-Yau manifolds (compact and non-compact) are here to stay: Calabi's condition, Ricci-flatness, turns out to translate into a certain quantum anomaly cancellation in a large class of quantum field theories, and is in that context inevitable, simply enforcing self-consistency. The fulcrum of Prof. Yau's proof, his combination of algebraic geometry with iterative non-linear PDE methods, turns out to have a close analogue in supersymmetric quantum field theory renormalization flow, which has been used over and over to advance understanding predominantly in string theory, but also in other branches of physics.

In such multiple-connected and interdisciplinary research that relates and correlates so many different subfields, attention to detail, fair assessment of contribution, and their interdependencies is both very difficult and highly commendable when properly done. The meticulous research that I have seen invested into the writing of *The Shape of Inner Space* and the story that it tells highlight the depth and strength of interactive and collaborative research that emanates from Prof. Yau.

Erdős Pál may well be world-famous for his prolific and wide-ranging research and publishing[2], but I cannot help but have a "physicists intuition" that the topography of Prof. Yau's collaborations across the various fields in mathematics and related disciplines runs as interestingly deep and broad.

Retro-Introspection

As impossible as it may be, one cannot avoid trying to measure oneself up to one's teacher and mentor, and take stock of what one could—*and should*—have done better. In addition, several of the phenomena and ideas on which I had worked on over the years turned out to be against the grain of the currently popular research and (as it happens) "before their time". In the past, I had always found a sympathetic ear when discussing those social aspects of research with Prof. Yau, but have nevertheless lost momentum and motivation. My humbling experience of presenting the closing talk of the August 2008 conference to such a varied and illustrious audience, as well as the closing dinner, and the informal tributes with friendly levity, caused me to face my own "inner space".

Seven years later, in 2015, my interest in constructing new Calabi-Yau models (in collaboration with Per Berglund) were suddenly and joyously revived, now embedding them in non-Fano ambient spaces. (After all, how hard can it be to embed a pair of points in a genus >1 Riemann surface?) To my increasing amazement, this is fairly straightforward and only a little more tedious than the well-trodden embeddings in Fano varieties. Non-Fano varieties being infinitely abundant and diverse, this also provides for an infinite (洪舒) play-ground for constructing and exploring Calabi-Yau n-folds, which has already been shown to harbor infinite stacks of discretely distinct complex Calabi-Yau n-folds, their moduli spaces leafing like Riemann sheets of an infinite book. Finally, this relaxation of positivity does require adapting many of the well-established techniques combining algebraic geometry, homological algebra, representation theory, and especially toric geometry[3]—which is what I hope will motivate the professional mathematicians' interest, possibly also the master, Prof. Yau himself.

If this were a physics paper, I'd know when it was finished. Even if this was a mathematical proof, I may have an idea as to when it was complete (though making me complete a rigorous proof may seem like pulling hen's teeth). However, I have no idea where a tribute such as this one can end…

So: many happy returns, Prof. Yau, and here's to another decade of unquenched curiosity, another decade of diverse endeavors, another ten years of splendid success—so as to meet again, and so as to toast again!

[2] Not a professional mathematician myself, I can only glean the mathematical significance of Erdős's mathematical research; the social aspects of the Erdős phenomenon and synergistic collaborations are however not lost on me.

[3] See arXiv:1606.07420 and arXiv:1611.10300.