MARIANGELA BERNARDI: TEACHING (April 2019)

As an Assistant Professor, I taught an introductory course for undergraduate non-science majors, and developed a graduate class (from scratch). As an Associate Professor I have added an intermediate level course, for undergraduate science majors, to my repertoire. I have also mentored the research and careers of students and postdocs.

Undergraduate teaching: Non-science majors:
The enrollment in the undergraduate class I teach has been typically about 80, and student evaluations of my teaching and accessibility have been good. In general, I enjoy teaching such 'service' courses, because I myself never took such a course, so I find it remarkable, and energizing, that so much of what we know about stars and galaxies can be communicated over the course of just one semester, with minimal use of equations.

I have also found that, in such courses, the difference between teaching and learning is sometimes painfully obvious. I constantly remind the students, and myself, that all things are 'easy' once they have been understood – but understanding something for the first time is difficult. But because understanding is difficult, it is too easy to accept passively what the teacher says. Bertrand Russell points out that passive acceptance seems rational because the teacher knows more than the pupils, but goes on to say that the habit of passive acceptance can be disastrous. Passive acceptance of facts I present in class is something I work aggressively to discourage – especially in this age of 'alternative facts'. Introductory astronomy is particularly well-suited to showing students the folley of passive acceptance (the long Dark Ages between the Greeks and the Renaissance), and the rewards that follow from asking and addressing carefully posed questions (the structure of the atom, energy from fusion and fission, the notion of an expanding Universe, the currently unsolved problems of the nature of Dark Matter and Energy and their relation to String Theory).

In recent years I have incorporated clickers and some other active learning strategies into my classroom. I use demonstrations, in class polling of multiple choice questions every 15 minutes or so, and make frequent connections between the material being studied and scientific results that were reported in the recent or current popular press.

My European colleagues sometimes wonder if there is any point in teaching science to non-science majors (such colleagues see even less point in doing it the other way round!). As the saying goes: Why gather bundles of sticks to build bridges you will never cross? I view this sort of class as an exercise, not so much in teaching known facts, but more in how to analyze them, and even more in inspiring the students with the desire to learn. The point is not to build a bridge; it is to learn to build, to want to build, and to then go on to build well.

Undergraduate teaching: Science majors:
Teaching science majors has its own special energy. One of the more rewarding aspects of this class is that this is where real change to the demographics of science can take place. I pay particular attention to fostering gifted female or other URM students. One such student was awarded fellowships which she used to do research at NASA JPL (Pasadena, USA) and the Max Planck Institute of Gravitational Physics (Potsdam, Germany) during the summer

of 2017. She took my *graduate* course in the Fall of 2017 and recently she has been admited to the grad program at the University of Chicago.

It was through this class that I first became involved in the Women in Physics group. After class one day, a group of students approached me with the idea of getting together as a group. Over the past few years I have participated in lunchtime discussions with our female majors about science, graduate school, research, balancing personal and professional responsibilities, etc.

Graduate teaching:
In my final year as an Assistant Professor I developed a new graduate course, *Galaxies: Structure, Dynamics and Formation*, which is now one of the four pillars of the Penn Astrophysics Graduate Program. This course covered various observational aspects of the subject (the many details involved in going from the photon counts at the telescope to calibrated photometry of extended objects, how one estimates velocity dispersions, how one accounts for selection effects such as those which arise from the fact that we typically see the most luminous objects to greater distances so most catalogs are biased against faint objects, and that the more distant objects appear redder than they are intrinsically because of the expansion of the universe), statistical estimation techniques to quantify the intrinsic correlations between observables (e.g., maximum-likelihood and principle component analysis), the physics of the objects (how to interpret the observed correlations using physical models of disks and triaxial virialized systems), and how one obtains information about their formation from data at a single epoch, or over a range of look-back times (e.g., using stellar population synthesis models).

I also use the course as an opportunity to familiarize the students with the numerical nature of most astrophysical research: Whereas class time is devoted to concepts, homework sets are computationally heavy. Some graduate students who join our program are not computer savvy! Therefore, although the enrollment in this course is typically less than 10, I usually spend hours outside of class time helping bring students up to speed with numerical methods. One of my goals is to ensure that our graduate students learn to use databases and big catalogs: In this era of big science, these are skills which transcend astrophysics and will serve them well even outside of academia.

Mentoring research:
There are many respects in which teaching in the classroom and mentoring graduate students and postdocs in their research differ. I said earlier that the former is about filling students with the desire to learn. The latter, mentoring, is almost an exercise in making oneself unnecessary.

One of the most important lessons which must be mastered as a PhD student – and which I emphasize to my students – is learning to think and analyse every aspect of one's work carefully. This is particularly true at the cutting edge of science, where we – student and mentor alike – typically do not know a priori what the results of a particular analysis, or the answer to a particular research question, will be. This ability to work carefully, to always be certain that it stands on firm ground, so that the next step can be taken with confidence, whether by oneself or others, is a formula for success well-beyond the PhD.

I have been successful in making myself unnecessary for three of my students (J. Hyde, A. Meert and J.-L. Fischer), who produced fine PhD's and have gone on to careers in industry. I also co-advised the PhD Thesis of E. Tundo at Padova. Recently I have involved a new first year student (F. Nikakhtar) in our Deep Learning for Morphology project. A. Fritz, N. Roche and V. Vikram were postdocs with me, went on to other postdocs, and remained in the field for several years thereafter. H. Dominguez-Sanchez has been a postdoc with me for the last two and half years and has just won a prestigious fellowship at the Institute of Space Sciences (IEEC-CSIC, Barcelona) to return to Spain. Recently, J. Ferrero also joined my group to work on the Deep Learning for Morphology and Spectroscopy projects. Finally, I played a significant mentorship role for F. Shankar, who is now tenured in the School of Physics and Astronomy in Southampton, and with whom I continue to collaborate.