MARIANGELA BERNARDI: TEACHING (February 2010)

At Penn, I have taught an introductory course for undergraduate non-science majors (six times), a graduate class that I developed from scratch (Spring 2010 will be the second time I teach it), and I have mentored the research and careers of students and postdocs.

Undergraduate teaching:
Having been educated in Europe, I had not taught before arriving at Penn. The enrollment in the undergraduate class I teach has been typically about 70, and student evaluations of my teaching and accessibility have been good. Somewhat to my surprise, I even managed to do a research project with one of these students! 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. Almost all of us have seen that when 'white' light passes through a prism, then all the colors of the rainbow come out the other side. Isaac Newton argued that 'white' light is in fact a mix of different colors – all the prism does is separate them out. Hooke (then President of the Royal Society) argued that the prism was making a more fundamental change to the light. Newton won the argument by blocking out all the colors that came through the prism save one, say green, and then making the green light pass through a second prism. It stayed green. But it took Newton – Isaac Newton – ten *years* to realize that all he needed to prove his point was to add the second prism!

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. He goes on to say that the habit of passive acceptance can be disastrous. It can cause one to accept as a leader whoever is established in that position. Passive acceptance of facts I present in class is something I work aggressively to discourage. 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). While I have yet to incorporate clickers and such into my classroom, I do use demonstrations, in class polling of multiple choice questions every 10 minutes or so, and I make frequent connections between the material being studied and scientific results that were reported in the popular press in the recent past.

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.

Graduate teaching:
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. I taught this course for the first time in Fall 2008, and received positive student reviews. 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 used the course as an opportunity to familiarize the students with the numerical nature of most astrophysical research – whereas class time was devoted to concepts, homework sets were computationally heavy. My experience convinced me that this would be better taught as a two course sequence – the first semester emphasizing the observations, and the second, the implications for models of galaxy formation (which are currently covered too rapidly at the end), particularly regarding the correlations between evolution and environment – i.e., the connection between cosmology, large scale structure, and galaxy formation.

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.

In mentoring graduate students and postdocs so far, I feel I have had the benefit of sampling both the best and the worst experiences. Interactions with my first postdoc were not very productive; although difficult, I acted quickly to improve things, and happily, the person who replaced him has been much more productive. In contrast, my first graduate student, Joey Hyde, was smart, hard-working, and an absolute pleasure to have as a colleague. In addition to doing great work for his thesis, he served for a while as the computer support person for the Astro group. I view him as a particular success story because his admission to the program was due in part to my reassuring the Admissions committee that I thought he had 'what it takes'. He successfully defended his PhD within 5 years of his arrival at Penn; if I am able to identify another student who is even half as good as he, I will count myself lucky. In addition, I am also mentoring graduate students of collaborators at other institutions (both domestic and international). The students have spent some time at Penn and have co-authored publications (in one case, the student served as the lead author, and will soon be starting a postdoctoral position). I expect they will return at least one more time before completing their degrees.