THE DISTANCES TO NEARBY GALAXY CLUSTERS

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The properties of the Fundamental Plane (FP) of E and S0 galaxies are analyzed using a sample of early-type galaxies in 8 nearby clusters of galaxies. I band CCD observations are presented for 631 galaxies in the A262, Cancer, A1367, Coma, Pegasus, and A2634 clusters, and in the NGC 383 and NGC 507 groups. Medium dispersion spectroscopic observations are presented for a sub-set composed of 212 galaxies. Combining this data-set with data taken from the literature, gives a FP sample of 294 galaxies. The clusters are chosen to span as large as possible a range of environmental conditions, from a rich, relaxed, X-ray luminous cluster like Coma, to rather poor groups of galaxies like the NGC 383 group. They are also chosen among the clusters that have the largest available samples of Tully-Fisher (TF) measurements, to allow an accurate comparison of the distance scales obtained using the FP and TF relations independently. Both selection criteria are aimed at quantifying the possible presence of environmental effects on the FP relation.

The scatter observed around the FP template implies that the distance to a single galaxy can be obtained, using the FP, with a 22% uncertainty (a 0.48 mag uncertainty on the galaxy distance modulus). The peculiar velocity estimates for the 8 clusters in the sample are all small, consistent with the clusters being at rest in the Cosmic Microwave Background reference frame. Monte Carlo simulations are used to quantify the effects of sample selection and measurement uncertainties on the FP template, and correct the resulting biases. After these corrections are applied, it is found that the properties of the FP do not change significantly as a function of the cluster richness, or as a function of the galaxy position within the cluster. Moreover there is very good agreement between the distance measurements obtained using the FP relation, and those obtained using the TF relation. These results are used to derive an upper limit of 5% on distance measurement uncertainties introduced by environmental effects.

A new relation, similar to the FP, is also presented. It is obtained from the traditional FP replacing the velocity dispersion parameter with a magnitude difference between a galaxy's measured magnitude and a characteristic magnitude for the entire cluster sample. If the characteristic magnitude could be measured with good accuracy (0.2 - 0.3 mag), this Photometric Fundamental Plane could provide distance measurements with an accuracy similar to that of the FP, being significantly more economical in terms of observational requirements, because it is a relation based entirely on photometric parameters.

Biographical Sketch

Marco was born on a cold night on January 19, 1965, in Milano (Italy). The story has it that after hearing the first crying sounds he made, the doctor could immediately prognosticate he would not be a singer. It is not known how good his medical skills were, but certainly he was a good prognosticator. Marco grew up in a rather peripheral neighborhood in Milano, where it was still possible to play soccer on the few broad enough sidewalks, without being killed by a car whose driver was trying to find the last available parking spot on that street. His parents Bruno, a freight train engineer, and Mariuccia, manager of a small candy store before becoming a housewife, always tried to make sure he was a good student, and also that he participated in some sport activity. They were quite successful in both attempts, and Marco spent the high school years trying to become a track and field star. However, by the time he reached the last year of high school, it was quite clear that his athletic capabilities would not earn him a living. At school things were going a lot better instead. Having enrolled in a technical high school (VII Istituto Tecnico Industriale Statale, in Milano) at the suggestion of his parents, he was doing quite well in all scientific and technical classes, and many professors and friends were suggesting to him to enroll in the engineering school of the Polytechnic Institute in Milano.

His interests were definitely more on the abstract side, though. After a brief flirt with archaeology, and some thoughts about paleontology (after all, all kids love dinosaurs at one stage of their life), he discovered math and physics in high school, and started reading in his free time about the highlights of modern physics and cosmology. Finally he settled his mind on physics, with the idea of going to study those "first three minutes of the Universe" that Steve Weinberg book had made popular. He got his high school degree in July 1984, and started going to college next October. The years at the Physics Department of the Università Statale di Milano were an intense period of study and personal development. For a few years cosmology was forgotten, while classical and quantum mechanics, electromagnetism, and particle physics dominated the scene. At the same time, he had met the "perfect" girl, Anna, and in a short time a stable relationship was born.

Then, by the time he had to choose a field to make it his own, it had become clear that in Milano no one was working on theoretical cosmology, but that there were a lot of astronomers doing interesting work on extragalactic astronomy and observational cosmology. Among them Peppo Gavazzi seemed to be the one who better enjoyed what he was doing, and so Marco decided to do his undergraduate thesis work with him. In this way he started working on star formation activity in spiral galaxies, and on the differences between isolated and cluster galaxies. In the end, still under Peppo's guidance, he began to work also on measuring distances to those galaxies. While working on his thesis he participated in an observing run at the Arecibo Observatory, where he met Riccardo Giovanelli, who stirred his interest in a possible PhD in the States. Having obtained his Physics Degree in July 1991, he applied to the Cornell Graduate School immediately thereafter, was accepted, got married to Anna in January 1992, and started his PhD "adventure" three days later.

The years at Cornell, working with Riccardo Giovanelli and Martha Haynes on distance measurements of nearby clusters of galaxies, were a combination of really hard work and many pleasant experiences. The joy of witnessing a new sunrise after a perfectly clear working night at Palomar or Kitt Peak was certainly enough compensation for having to study statistical mechanics once again. Also special were the short trips to some of the best natural wonders on Earth (Grand Canyon and Sequoia National Park certainly at the top of the list) that he could associate to some of those observing runs. Living in Ithaca was a very pleasant experience too, once the shock of the first never-ending winter had become just a memory. By the time his thesis was finished, the family had expanded, with the birth of Leonardo on May 1996, and even before that, with the adoption of Penelope, a beautiful gray female cat.

Now Marco has a job at the European Southern Observatory, in Garching, a village at the northern periphery of Munich (Germany). Milano will be only a six hour trip away, and this should compensate for the fact that people all around will be speaking a totally alien language....

Il più certo modo di celare agli altri
i confini del proprio sapere,
è di non trapassarli.

Giacomo Leopardi, Pensieri

Acknowledgments

This work has benefited from the help of many people, and these few lines are here to say a really big thank you to all of them. At the top of the list are of course Riccardo Giovanelli, my adviser, and Martha Haynes. I cannot even try to quantify the immense debt of gratitude I have towards them. They were simply fantastic all the time, from before I arrived in Ithaca, to after it was time to leave. Also the other members of my special committee were always helpful. I had many opportunities to appreciate the vast astronomical knowledge of Terry Herter, the unbelievable all-around knowledge of Phil Nicholson, and the deep physical and astronomical insight of Dick Lovelace. To them goes my gratitude also for being extremely patient while I tried to finish writing this thesis.

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Brett, Katie, and Danny were the friends who helped me survive five years at Cornell, and in Ithaca. Also in the list are Tyler, Liese, Jean-Luc, Julie, Matt, Jamie, Adrick, and Josè Maria. I will always remember the volleyball and softball games, the nights playing Balder-Dash or naval battle, or the moments of relaxed conversation in Liese, Tyler and Katie's office. Chris, Tracy, Peter, and all the guys at WQNY Q104FM / The Wave constantly provided fantastic music and a lot of jokes that made the snow a little less unbearable. My friends in Milano, Bianca, Enzo, and Miriam, never forgot me during these long years, and receiving one of their E-mail messages would always make that day a little bit special. One special thank to Prof. Costantinos Paizis, for his teachings, and the training he provided during his Cosmic Physics class. Having taken that class made survival at Cornell a lot easier. My parents, Bruno and Mariuccia, were always supportive of my aspirations, and they contributed all they could to help them become a reality, even though they were probably scared to death about the idea of having their

son living some six thousand miles away. My wife, Anna, endured five years living with a husband that was most of the time too busy to pay attention to her. Fortunately Peppo's discouraging prognostication about the likelihood that a successful PhD would be paralleled by a quick divorce, did not become true. To her goes my gratitude and my love.

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