THE SCALING RELATIONS OF ELLIPTICAL GALAXIES

Luigi Secco

(The present programme is linked with Programme 12 of Mauro D'Onofrio)

Around the end of 1980s it has been discovered that all the galaxies either ellipticals or spirals belong to a Fundamental Plane which connects their effective radius, the mean surface brightness within it and their kinetic energy per unit mass.The projections of this plane on the coordinate surfaces yield what usually is called the galaxy scaling relations. Because we are dealing with virialized two-component structures the first tool to build up was the tensor virial theorem extended to two components in order to look for a possible solution of the problem. This extremely powerful tool has been developed since the beginning of 1980s by a precious collaboration between Padua and Bonn Universities (Brosche, Caimmi e Secco, 1983; Caimmi, Secco e Brosche, 1984; Caimmi e Secco, 1992) and is still in progress at our Astronomy Department (e.g.: Caimmi, 2003; Caimmi e Marmo, 2003).

By using this theory applied to a bright component completely embedded inside a dark halo we discovered that exists a minimum value for the Clausius' virial energy (Secco, 2000, 2001; Marmo and Secco, 2003) This is due to an induced scale length on the gravitational field of the luminous baryonic component by the tidal effect of the dark matter. One of the main property of this minimum, corresponding to a special configuration of minimum peculiar kinetic energy, is to share in about the same amount the self-potential energy of the inner component and its tidal-potential energy.
As soon as the system virializes at this special configuration some of the main features of the Fundamental Plane begin to appear with a precise physical meaning.
Our aim is now to develop this research branch in order to compare all the outputs of this theory with the observables and to understand, as soon as possible, what are its constraints on the cosmological processes of galaxy formation.

The research program is divided as follows.
A) One of the main theoretical result of the Clausius' minimum theory is that the coefficients of the Fundamental Plane of the ellipticals and also the mass/luminosity ratio of the tilt are depending only on the dark matter universal profile in the inner region which contains most of the baryonic component. A density profile as 1/r^0.5 is able to explain these features and also to reproduce the Faber-Jackson relationship fairly good.
Recently the exploration has been extended to the thermodynamical aspects (Secco, 2005; Secco e Marmo, 2003) related to this special configuration we call of tidal radius. It appears that the induced scale length by the dark matter works as a true confinement dimension for the stellar system like the tidal radius due to the gravity of the Galaxy for the Globular Clusters (Secco, 2003; Caimmi e Secco, 2003; Caimmi, 2004).
Moreover the result that the main dynamical effects are depending only on the inner universal profile suggest a more general aim: to explain with a common mechanism why Globular Clusters, Galaxies and Galaxy Clusters belong to the called cosmic metaplane (Burstein et al. 1997).
For this reason we began to investigate more general two- component system with homeoidally striated ellipsoids (Caimmi e Marmo, 2003). Now we are able to deal with Hernquist profile (Hernquist, 1990) for the bright component and NFW profile (Navarro,Frenk, White, 1997) for the dark matter halo both unified into the general Zhao profiles Zhao (1996) with variable concentrations. The first results appear in Marmo (2003) where there is also the first attempt to connect these general profiles with those obtained by deprojecting the Sersic law. The study of the trends of the gravitational potential and of the potential energy in all their different forms according to the tensor formulation are also contained.

B) In order to prove directly the existence of this induced scale length which is on the basis of the dynamical theory we tried to look at the world of spirals.Van der Kruit (1979) for the first time observed some cut-off in some spirals viewed edge on. The possible connection between

these cut-off and the tidal radius has been investigated in a thesis for the degree in Astronomy with the title: Cut-off in spiral galaxies and tidal effects due to dark halos, developed by Dr. Andrea Raffaele (Rel.L.Secco,R.Caimmi,G.Galletta-2003). This branch has to be extended and it appears absolutely necessary for moving to the translation of the present Clausius' minimum theory to the scaling relations for the spirals.

Project 1

In order to extract from the present theory all its capability we need to translate the results obtained on the k-space introduced by Bender et al. (1992). Noteworthy it will be the comparison between the ZOE region (zone of exclusion) predicted by theoretical grounds to be different for dwarfs and for giants ellipticals and the same regions in the k-space.
An other important test will be the connection of the Line of Avoidance in the Kormendy Plane with the ZOE. The observative counterpart of our theory will take advantage of the interaction with the WINGS Project (see D'Onofrio).
An other way to attack the problem will be to continue the exploration by N-body simulations (Valentinuzzi et al.2003) in order to study how the relaxation mechanism of a stellar dominated component, completely embedded inside a dark halo, builds the random kinetic energy via Landau damping for virialized at the special configuration.

Project 2

It is of great relevance to explain the correlations highlighted by Pohlen et al. (2000) and by Kregel et al. (2002) between the cut-off radii and the scale length in the spiral galaxy disks, by using the Clausius' minimum theory.
That will open the road to the translation of the main results obtained for the pressure supported ellipticals to the angular momentum supported spirals.

Personnel:

Secco Luigi, prof.associato
Caimmi Roberto, ricercatore,
D'Onofrio Mauro, ricercatore,
Valentinuzzi Tiziano, dottorando
Marmo Chiara, dottoranda
Merlin Emiliano, borsista (dal 2005)

Collaborations:

Prof.Volker Mueller, University of Potsdam (Germany)
Research Group of Profs. Ralf Bender and Roberto Saglia.at the Universitaets-Sternwarte in Scheinerstrasse in Muenchen (Germany).
Dr. Olivia Garrido, Observatoir Haute Provence, Marseille.
Prof. Peter Brosche of the Bonn University, Sternwarte of Hoher- List (Germany).

Gianni Fasano, INAF Padova
Daniela Bettoni, INAF Padova

Research Products:

The products of the research are published papers on international journals or proceedings.
The following list includes only the works in which are involved the members of the Astronomy Department cited in sec. 4.b
The pubblications are common to both program: Secco+ D'Onofrio
Year 2000: 3 papers, with referee 3
Year 2001: 15 papers, " 8, no referee 7
Year 2002: 4 papers, " 2, " 2
Year 2003: 14 papers " 5, " 9
Year 2004: 4 papers " 1, " 3

List of 5 most representative publications:

SECCO L. (2000) Double gravitational bound system in virial equilibrium: tidal scale legth on one subsystem by another. NEW ASTRONOMY, vol.5/7, pp.403-421 ISSN:1384-1076.

SECCO L. (2001). The Fundamental Plane as a consequence of Clausius' virial minimum. NEW ASTRONOMY, Vol.6, pp. 339-357 ISSN:1384-1076.

C.MARMO, SECCO L. (2003). Clausius'virial vs.total potential energy in the dynamics of a two-component system. NEW ASTRONOMY. vol. 8, pp. 629-644 ISSN: 1384-1076.

CAIMMI R., MARMO C. (2003). The potential-energy tensors for subsystems. IV. Homeoidally striated density profiles with a central cusp. NEW ASTRONOMY. vol. 8, pp. 119-140 ISSN: 1384-1076.

CAIMMI R. (2004). The virial theorem for subsystems: application to a globular cluster within a galaxy. ASTRONOMISCHE NACHRICHTEN. vol. 325, pp. 1-6 ISSN: 0004-6337.