ASTRONOMIA E ASTROFISICA
SCIENTIFICA

COLLANA DIRETTA DA ENRICO COSTA ED ENRICO MASSARO

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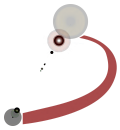

La più sublime, la più nobile tra le Fisiche scienze ella è senza dubbio l'Astronomia. L'uomo s'innalza per mezzo di essa come al di sopra di se medesimo, e giunge a conoscere la causa dei fenomeni più straordinari.

Giacomo Leopardi

Negli ultimi anni si è assistito ad una grande crescita di libri dedicati alla descrizione dei primi istanti dell'universo e delle sue complicate proprietà fisiche o alla scoperta di un sempre crescente numero di pianeti in rotazione attorno a stelle vicine.

Gli argomenti trattati nelle ricerche astronomiche spaziano in un panorama molto più ampio, spesso poco noto alla maggioranza dei lettori. Molti dei risultati recenti devono essere confermati ed ampliati e ciò richiede un numero sempre più grande di osservazioni e di accurate analisi dei dati così ottenuti. Accade spesso che le tecniche i dettagli di questi lavori non riescono ad essere descritti come meriterebbero nel ristretto spazio di un articolo su rivista.

Questa collana si prefigge di colmare in parte questa lacuna pubblicando testi che forniscano agli specialisti, come a coloro che affrontano queste impegnative ricerche, una documentazione che ne descriva i diversi aspetti.

Ad essi si affiancheranno anche cataloghi e raccolte di dati, un fondamentale *thesaurus* per le ricerche astrofisiche, e testi più semplici di livello introduttivo.

La collana si divide in due sezioni: in questa sono ospitati i volumi con un taglio e un orientamento scientifico.

Luigi Secco

Galaxy Dynamics

On the Galaxy Fundamental Plane of Early–Type Galaxies
A New Interpretation of the Enigma
Volume 2

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ISBN 978-88-255-2820-6

I st edition: February 2020

So that I will not waste Your Gift

Contents

Preface

The aim of this second volume of Galaxy Dynamics is to widely discuss the Fundamental Plane (FP) of galaxies (the ellipticals as prototypes). As anticipated in the first volume, FP is the two dimensional parameter space where galaxies land at virialization. Its theoretical interpretation is still an open problem and its relevance has always been great since its discovery in 1987 (e.g., Dressler, 1987; Djorgovski and Davies, 1987). Indeed the understanding of the fate of virialized structures on galaxy scale means the understanding of the fate of all virialized cosmological structures from *globular clusters* to *galaxy clusters*. This kind of unification is merit of Burstein *et al.* (1997) in the discovering of the *Cosmic Metaplane*, i.e., by having highlighted some common features for all the self gravitating structures in the huge range of about $10^6 \div 10^{15}$ solar masses.

In Chapt. 1 some historical notes with the main features of galaxy FP and its enigmatic aspects, starting from the values of its exponents A and B, are introduced. A review of some relevant interpretative analyses to understand them follows, in particular a possible physical reason for the *tilt* characterized by the exponent α_t. The final result points out the impossibility finding an exhaustive explanations to all the FP features without meeting a *fine tuning problem* for some parameters (Chapt. 2). In Chapt. 3 a new strategy, put forward by myself, is exposed starting from the ongoing questions about the galaxy end–state after violent relaxation [1, 10]. The new approach is based on the inclusion of a dark matter (DM) halo in which the baryonic stellar component (B) is embedded. That asks for the writing down of virial equilibrium of B taking into account we are dealing no longer with a single system but with a two–component one. Now the question is: what is the term in the virial theorem to add to the self–gravitating potential energy when a DM halo exerts its dynamical effect on the B component? Chapt. 4 is dedicated to answering this question. The key lies in the Clausius' virial energy (CV) which involves scalar product

between forces and positions. So the right answer turns out not to be the interaction energy but the tidal one coming only from the fraction of DM which is inside the B component. In Chapt. 5 the most relevant property of CV is highlighted. We have indeed discovered that CV, in a two–component system, is not a monotonic function of the virial dimension of stellar component once fixed DM dimension, but it exhibits, under some conditions, a maximum for a special B dimension. This maximum corresponds to a minimum of macroscopic pressure in order to substain the visible structure. It enjoys many mechanical and thermodynamical properties, in particular the maximization of the entropy of B subsystem. Writing down the virial theorem at this special configuration, the theory of Clausius' virial maximum (CVM) is built up by a linear model producing many outputs in fair agreement with observed scaling relationships and giving reason for the main features of FP (Chapt. 6). Djorgovski (1992) cosmological degeneration is also recovered, that means the way in which FP (through its exponents A, B, α_t) looses memory of the initial density perturbation spectrum conserving it only inside the projections on coordinate planes of parameter space, e.g., into Kormendy and/or Faber–Jakson realtionship. In Chapt. 7 we move from a linear to non–linear model adopting for B component the King's model with cut–off. That marks the continuity of ellipticals with globular clusters, also belonging to FP. For the dark matter halo a power–law density profile is assumed again with an exponent $d = 0.5$ (with a small homogeneous central core as in linear model) to match A and B and α_t FP's exponents in B–band. The derivation of theoretical equations of FP, of the *tilt* and of the Zone of Exclusion (ZOE) are then discussed in Chapt. 8. To prove the prediction capability of CVM theory, the galaxy mass–size relationships are explored in Chapt. 9 within a ΛCDM cosmological scenario comparing them with those of Tortora *et al.*(2009) obtained from observations. In the Chapt. 10 the news introduced in this approach are summarized with the general conclusions. The aim of the last Chapt. 11 is to collect a description of the cosmological environments starting from the old ones without DM (Russian and American School), moving then to those with Cold (CDM), Hot (HDM), Warm (WDM) DM, with the purpose of looking for the scenario able to justify the power–law exponent $d \simeq 0.5$ used for the DM halo in the CVM theory. The WDM cosmological model appears to be the most

suitable one for this aim, implying the *sterile neutrinos* with mass of the order of *keV* as DM particles. So the interpretation of FP by CVM theory also becomes an indication for DM probable candidates.

As Vol. 1, the level of the present textbook corresponds to that of a Master Degree in Astronomy and/or Astrophysics. Necessary requirements are: basic knowledge of galaxy dynamics.

A fruitful help for the reader is located in the Introduction.

Padova, July, 2018.

Links to Vol. 1

— [1, *n*]= Chapt.n of Vol. 1
— [1, *n.n*]= sect.n.n of Vol. 1
— [1, *Ref.*]= References in Vol. 1