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Dynamical Non-Homology and the Tilt of the Fundamental Plane

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1. The 'tilt' of the Fundamental Plane

The Fundamental Plane (FP) of elliptical galaxies is the manifestation of the two-dimensional nature of the relations existing among the observed global properties of this class of objects. One of the main questions posed by the existence of such relations is that they seem to be in disagreement with the virial theorem. This could be ascribed to a systematic change of M/L along the FP: $M/L \sim L^{\beta} I_e^{\gamma}$. The trend of M/L should then be accounted for. The question remains, however, whether the observable quantities properly represent the global physical quantities involved in the virial theorem. If this is not the case, the non-homology of E's has to be taken into account. In particular, one may ask if the central velocity dispersion is suitable to represent the kinetic energy of a galaxy.

2. Kinetic energy of random and rotational motions

There are two reasons to believe that σ_0 is not fully representative of the kinetic energy: *i*) ellipticals rotate, and, even if rotation does not play a major role, its contribution to the kinetic energy is not negligible. Moreover, the rotation is not correlated to the velocity dispersion; *ii*) the shape of the velocity dispersion profiles (VDP) varies from galaxy to galaxy.

Our first aim was thus to derive, from the kinematical data, two quantities which represent the relative kinetic energies: $v_{eq} = \sqrt{2\, T_{rot}}$ and $\sigma_{eq} = \sqrt{2/3\, T_{\sigma}}$. The derivation starts from the deprojection of the kinematical data from the integration along the line of sight. The kinetic energies (inside the effective semi major axes) are then computed under some simple assumptions on the spatial symmetry of the kinematical quantities and of the matter distribution. The procedure has been applied to a sample of 40 'bona-fide' E's for which extended kinematical data are available. For details on the sample and on the computations see Busarello et al. 1996.

3. Dynamical non-homology

The shapes of the VDP of ellipticals show a definite trend: the gradients are higher in the systems with higher σ_0. This trend is reflected by the computed kinetic energies: the equivalent velocity dispersion turns out to be related to σ_0 by $\sigma_{eq} \sim \sigma_0^{0.8}$, so that the kinetic energy of random motions is proportional to $\sigma_0^{1.6}$ instead of σ_0^2 (as it is usually assumed). Although not easy to explain, this result seems to favour a dissipative scenario for the formation of E's, in which 'hotter' systems suffered a more effective 'cooling', showing now a steeper outward decrease of the velocity dispersion. The existence of this 'dynamical' non-homology suggests a possible explanation of part of the observed tilt of the FP. We derived the FP parameters for our sample by including in the 'dynamical' term three different quantities respectively:

i) as usual, the central velocity dispersion σ_0;

ii) the velocity dispersion σ_{eq} derived from the relative kinetic energy ;

iii) a 'velocity' V derived from the total kinetic energy: $V = \sqrt{3\sigma_{eq}^2 + v_{eq}^2}$.

The table lists the FP solutions corresponding to the three cases (the last column gives the r.m.s. deviations in the r_e direction).

TABLE 1. FUNDAMENTAL PLANE SOLUTIONS

v	a	b	δ_{r_e}
σ_0	1.11 ± 0.2	-0.91 ± 0.1	0.13
σ	1.53 ± 0.2	-0.92 ± 0.1	0.13
V	1.68 ± 0.2	-0.89 ± 0.1	0.12

FP equation: $log(r_e) \propto a\ log(v) + b\ log(I_e)$.

4. Conclusions

The tilt of the FP is dramatically reduced by the introduction of the specific kinetic energy in place of the central velocity dispersion. This quantity more accurately represents the real global dynamical status of the systems, and is related to σ_0 in a non-trivial way because of two reasons:

i) a substantial non-homology of the kinematics of E's;

ii) the presence of a non-negligible rotational support.

Most of the tilt ($\sim$ 55%) seems to arise from the dynamical non-homology of the systems, i.e. from some systematic changes of the relations between the observed 'local' quantities used to construct the FP and the physical 'global' quantities that appear in the virial theorem. The rotational support contributes to $\sim$ 15% of the tilt (see also Prugniel & Simien 1994), while the remaining $\sim$ 30% of the tilt can be easily explained by stellar population effects (Prugniel & Simien 1996), and by the non-homology in the brightness distribution (Prugniel, private communication), without any need of invoking trends in the M/L ratio, which, on the other hand, seem to be very hard to reconcile with the observed tightness of the FP.

References

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