PROCEEDINGS OF SCIENCE

New phenomenological constraints for dark matter models in disks

David Roscoe[*]
Applied Mathematics Dept
Sheffield University
Sheffield S17 4HN, UK

Email: `D.Roscoe@shef.ac.uk`

We describe an analysis of four large samples of rotation curves to show how bulge-subtracted discs appear to be associated with a *class* of (at least four) fundamental planes. The existence of this class of fundamental planes can be considered as a constraint to be satisfied by dark matter models.

Baryons in dark matter halos
5-9 October 2004
Novigrad, Croatia

---

[*] Speaker.

Published by SISSA http://pos.sissa.it/

PoS(BDMH2004)051

1. Introduction

This paper is an overview of Roscoe [1] which describes the analyses of four large optical rotation curve samples showing how the hypothesis that *bulge-subtracted discs are associated with a class of (at least four) fundamental planes* is supported by the data as a near-statistical certainty.

We were led to consider the idea that rotation in bulge-subtracted discs might be described - in an overall statistical sense - by power laws in the form $V_{rot} = AR^{\alpha}$, with the parameters A and α being determined empirically for each galaxy in turn. We began by considering the small sample of 21 ORCs published by Rubin et al [2] from this point of view. Of this sample, only twelve manifested reasonably monotonic behaviour and so were selected *on these grounds alone* as reasonable candidates for a power law analysis. Subsequently, a linear regression of the model $\ln V_{rot} = \ln A + \alpha \ln R$ onto each of the ORCs provided twelve sets of parameter-pairs $(\alpha, \ln A)$.

1.1 The $\alpha : \ln A$ correlation

The first clear result of this mini-analysis was that α and $\ln A$ appeared to be strongly correlated - and this aspect has now been analysed in detail using Persic & Salucci's [3] folding solution for 900 ORCs from the Mathewson et al [4] sample (Roscoe [5]). See figure 1 (left panel). A detailed analysis of this diagram showed there to be a very strong dependency on luminosity properties to the extent that a model of the form

$$\ln A = F(\alpha, M, S), \tag{1.1}$$

where M and S are absolute magnitude and surface brightness respectively, accounts for about 95% of the variation in the scatter plot.

1.2 A multi-modal distribution for $\ln A$?

Briefly, the twelve $\ln A$ values seemed to cluster around four distinct values. Although the sample was too small to draw any definitive conclusions, it allowed a prediction about the distribution of $\ln A$ values to be made which could be further tested. The actual $\ln A$ distribution of the 900 Mathewson et al ORCs folded by Persic & Salucci [3] is given in figure 1 (right panel). The vertical solid bars indicate the *predicted* positions of the peaks, based on our analysis of the Rubin data, whilst the vertical dotted lines indicate actual peak centres. The correspondence between the peak positions, predicted on the basis of the twelve Rubin et al [2] galaxies and the actual peak positions is clearly remarkable.

2. The analysis of three more samples

Subsequently, three further samples of 497, 1100 and 405 ORCs were analysed from this point of view - Dale et al [6], [7], [8], [9], [10], Mathewson & Ford [11] and Courteau [12]. Apart from the ORC data, each analysis required estimates of V_{rot} and a correspondingly calibrated Tully-Fisher relation. In all cases *except* Mathewson & Ford, we used the observing astronomer's V_{rot} estimates and TF calibrations. The Mathewson & Ford eye-ball estimates of V_{rot} turned out to contain significant systematic errors, and so V_{rot} for this sample was replaced by V_{opt} at R_{83} and we used the Dale et al TF calibration since they state that their way of estimating V_{rot} recovers V_{opt} at R_{83} in ideal circumstances.

PoS(BDMH2004)051

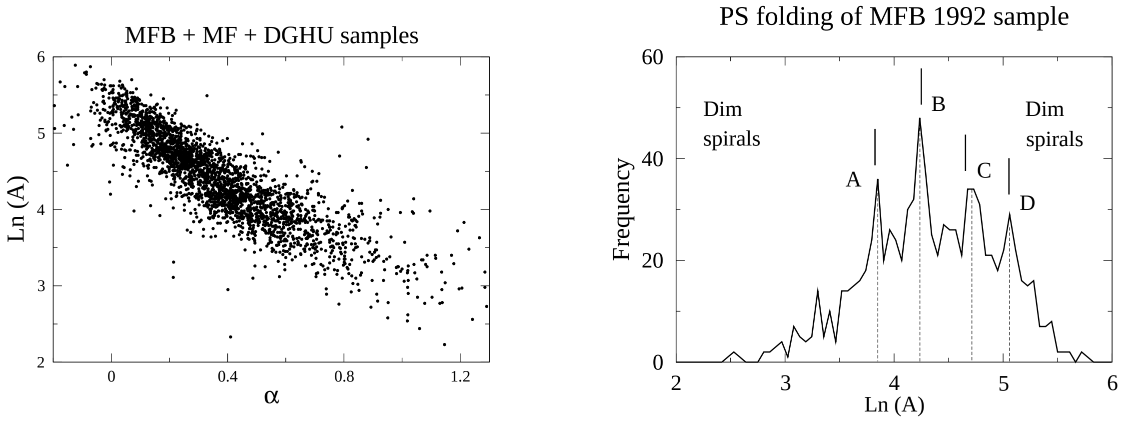

Figure 1: Left-panel shows the $(\alpha, \ln A)$ scatter plot. The right-panel shows the $\ln A$ distribution for the Mathewson et al [4] sample with Persic & Salucci folding. Vertical dotted lines indicate actual peak centres. Vertical solid bars indicate *predicted* peak centres from the Rubin et al [2] sample.

The corresponding $\ln A$ distributions are shown in figure 2. The left-end of each diagram corresponds to the dim end of objects. We see that, except for the dim-end A-peak in the Dale et al and Courteau samples, the peak structure is very well reproduced across the four samples. These results, combined with extensive use Monte-Carlo simulations, finally enabled us to establish to a very high degree of statistical certainty that the parameter $\ln A$ appears constrained to take on discrete values $k_1, k_2, \ldots$. Combining this with (1.1) which showed $\ln A = F(\alpha, M, S)$, then we must have $F(\alpha, M, S) = k_1, k_2, \ldots$. Thus it appears that spiral galaxies are constrained to exist on one of a set of distinct state planes in the three-dimensional (M, S, α) space - reminiscent of the fundamental planes for ellipticals.

3. Concluding comments

Apart from the importance of good Tully-Fisher calibrations and linewidth determinations, the successful extraction of the multi-modal distribution for the $\ln A$ data is also critically dependent on the quality of the folding process and the bulge-subtraction process. These are discussed in detail in Roscoe [1].

We have analysed four separate large ORC samples to show that the multi-modal $\ln A$ distribution hypothesis for bulge-subtracted galaxy discs is supported by the data at the level of virtual certainty. The immediate significance of the phenomenology is that any given spiral galaxy appears to be constrained to evolve over one of a set of distinct state planes, existing in a three-dimensional (M, S, α) space where M is absolute magnitude, S is surface brightness and α is a parameter computed for each galaxy from its rotation curve.

Whatever the truth of the matter, it seems certain that the existence of the distinct state planes for bulge-subtracted discs poses very difficult questions for the standard galaxy formation theories, and will have a potentially profound affect on our developing understanding of galactic dynamics and evolution in particular, and the cosmos in general.

PoS(BDMH2004)051

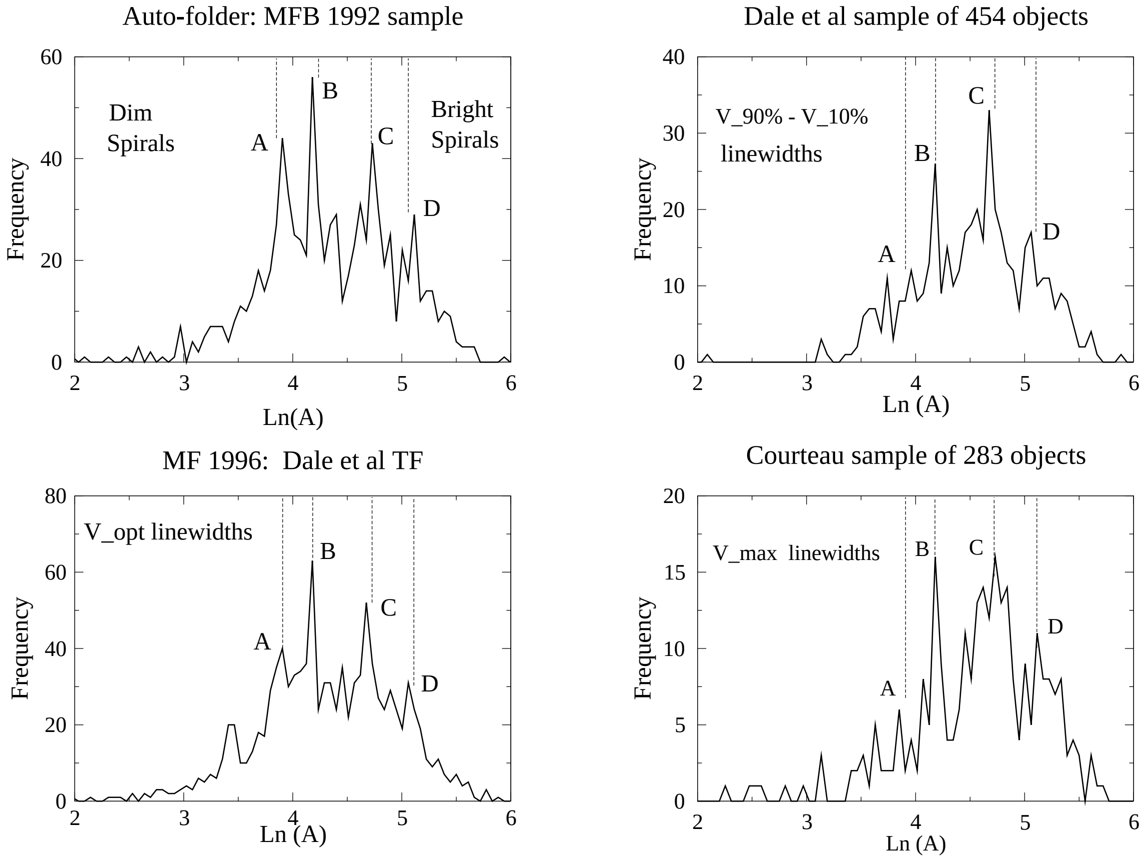

Figure 2: Top-left panel is Mathewson at al data, top-right panel is Dale et al data, bottom-left panel is Mathewon & Ford data, bottom-right is Courteau data.

References

[1] Roscoe D.F., 2002a, Astron. Astrophys, 385, 431-453

[2] Rubin V.C., Ford W.K., Thonnard N. 1980, ApJ 238 471

[3] Persic M., Salucci P., 1995, ApJS 99 501

[4] Mathewson D.S., Ford V.L., Buchhorn M. 1992, ApJS 81 413

[5] Roscoe D.F., 1999b, A&A,343, 788-800

[6] Dale DA, Giovanelli R, Haynes M, 1997 AJ 114 (2): 455-473

[7] Dale DA, Giovanelli R, Haynes MP, Scodeggio M, Hardy E, CampusanoLE, 1998 AJ 115 (2), 418-435

[8] Dale D.A., Giovanelli R, Haynes M.P., 1999, AJ 118 (4), 1468-1488

[9] Dale D.A., Uson JM, 2000, AJ 120 (2), 552-561

[10] Dale D.A., Giovanelli R, Haynes M.P., Hardy E, Campusano LE, 2001,AJ 121, 1886-1892

[11] Mathewson D.S., Ford V.L. 1996, ApJS 107 97

[12] Courteau S., 1997, AJ, 114, 6, 2402-2427

PoS(BDMH2004)051