

LETTERS

<https://doi.org/10.1038/s41550-018-0498-9>

nature
astronomy

Absence of a fundamental acceleration scale in galaxies

Davi C. Rodrigues ^{1,2*}, Valerio Marra ^{1,2*}, Antonino del Popolo^{3,4,5} and Zahra Davari⁶

VALERIO MARRA

MARRA.COSMO-UFES.ORG



Um grande obrigado ao Ioav! (&Miguel!)

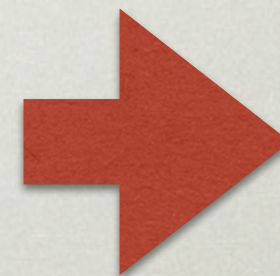
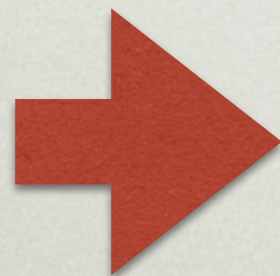
Chamada de Projetos nº 70/2013 - 3º Cronograma - Atração de Jovens Talentos

Ordem	Proponente	Bolsista - BJT	Instituição Executora
BJT - Nível A			
1	ROBERTO DE CAMPOS GIORDANO	JULIO JOSE LADO GARRIDO	UNIVERSIDADE FEDERAL DE SÃO CARLOS
2	PAULO AMERICO MAIA NETO	VALERIO MARRA	UNIVERSIDADE FEDERAL DO RIO DE JANEIRO
3	MARILENE HENNING VAINSTEIN	LUCELIA SANTI	UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
4	ROBERTO AVELINO CECILIO	FABIO GUIMARAES GONCALVES	UNIVERSIDADE FEDERAL DO ESPÍRITO SANTO

Heidelberg



... & ...



UFRJ

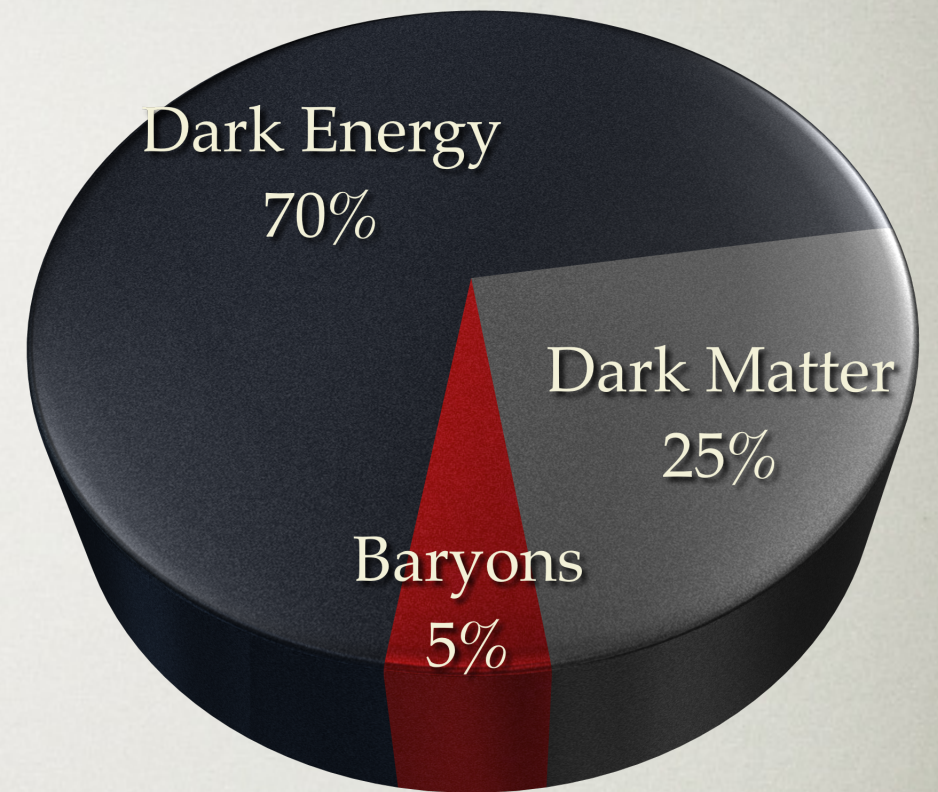


UFES

Dark Matter?

Present-day observations support the Cold Dark Matter paradigm.

However, still no direct/indirect detection.
Will there be?



Natural to look for alternatives.

MOND has been successful at describing
the internal dynamics of galaxies.
(MOdified Newtonian Dynamics)

$$\text{Newtonian acceleration } \mathbf{a}_N = \mu \left(\frac{a}{a_0} \right) \text{ observed acceleration } \mathbf{a}$$

fundamental acceleration scale

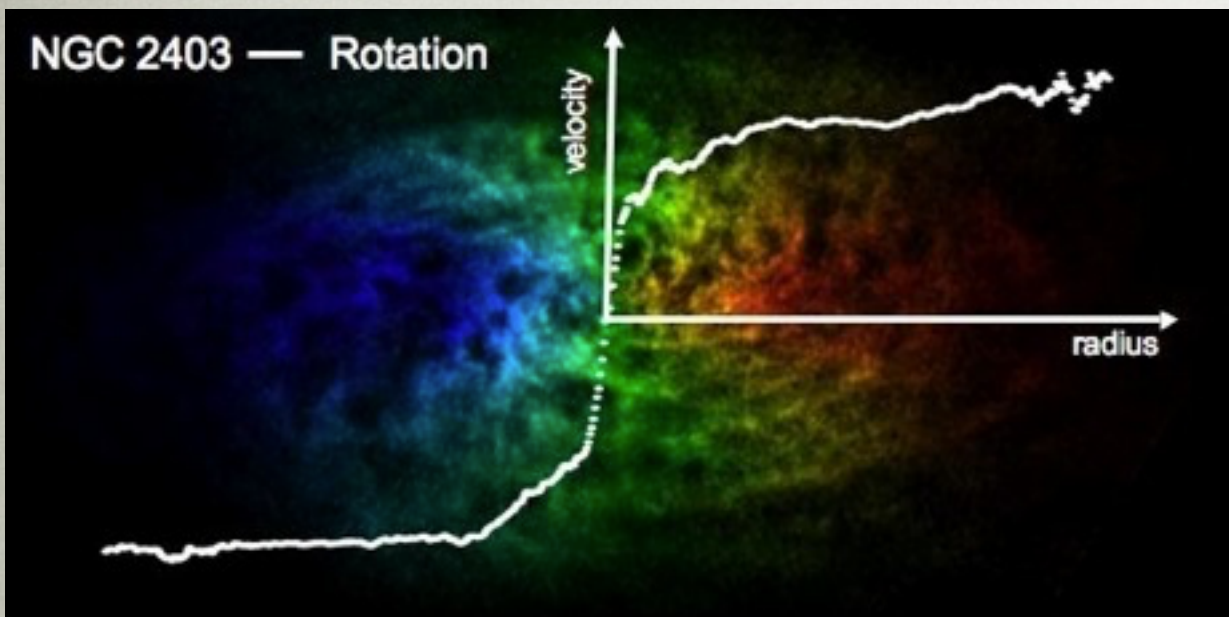
$$a \gg a_0$$

$$a = a_N$$

$$a \ll a_0$$

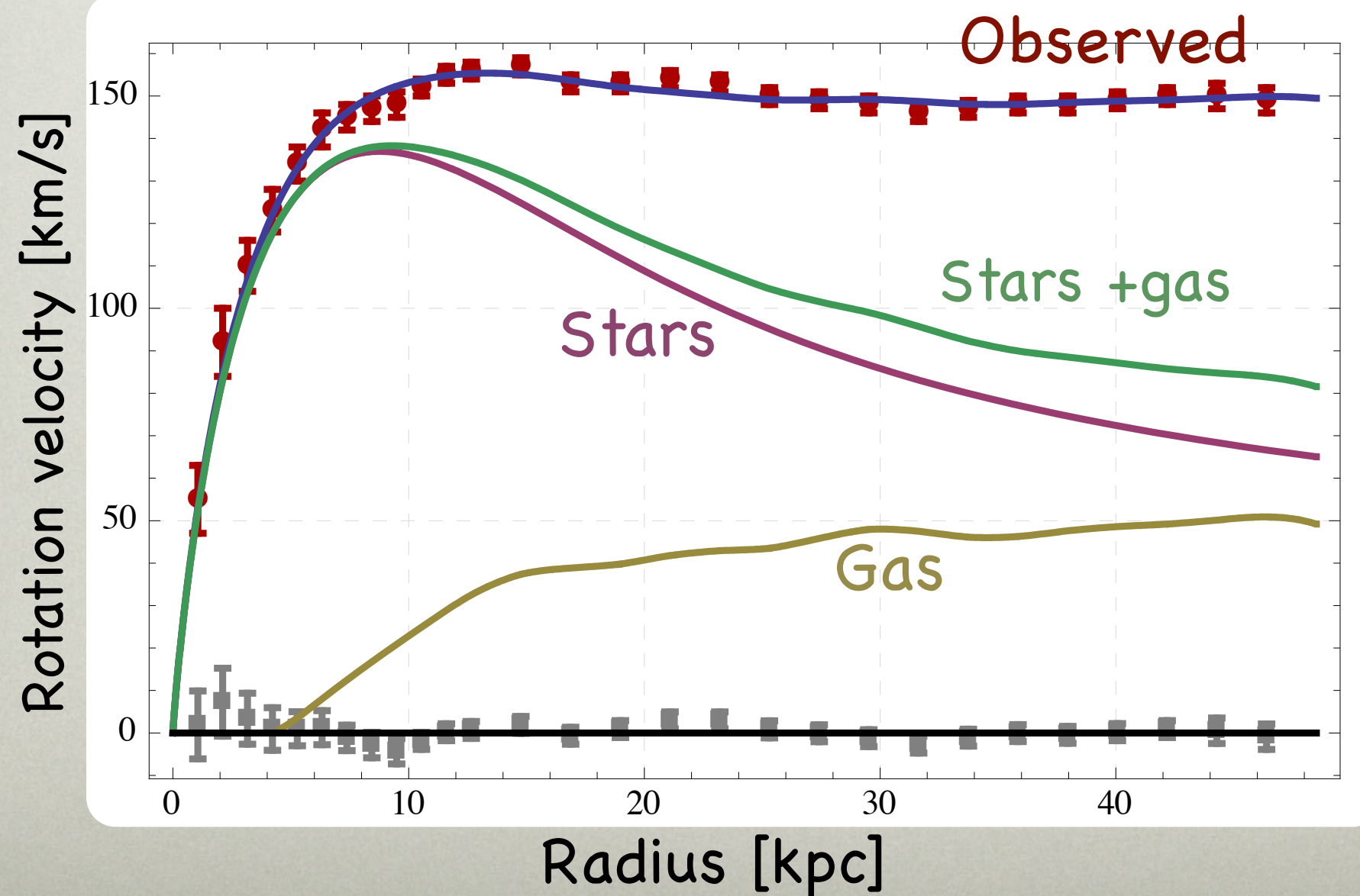
$$a^2 \propto a_N$$

Dark Matter?



One can fit the data by:

1. adjusting the DM halo
2. adjusting the acc. scale a_0



Acceleration scale?

MOND is successful at describing many galaxies.

However, it could be just a phenomenological theory and one expects two possibilities:

1. fundamental theory $\rightarrow$ same a_0 for every galaxy
2. effective theory for DM $\rightarrow$ case-by-case a_0

The Radial Acceleration Relation

In disk galaxies, there is a sharp correlation between the observed acceleration and the acceleration inferred from baryonic matter.

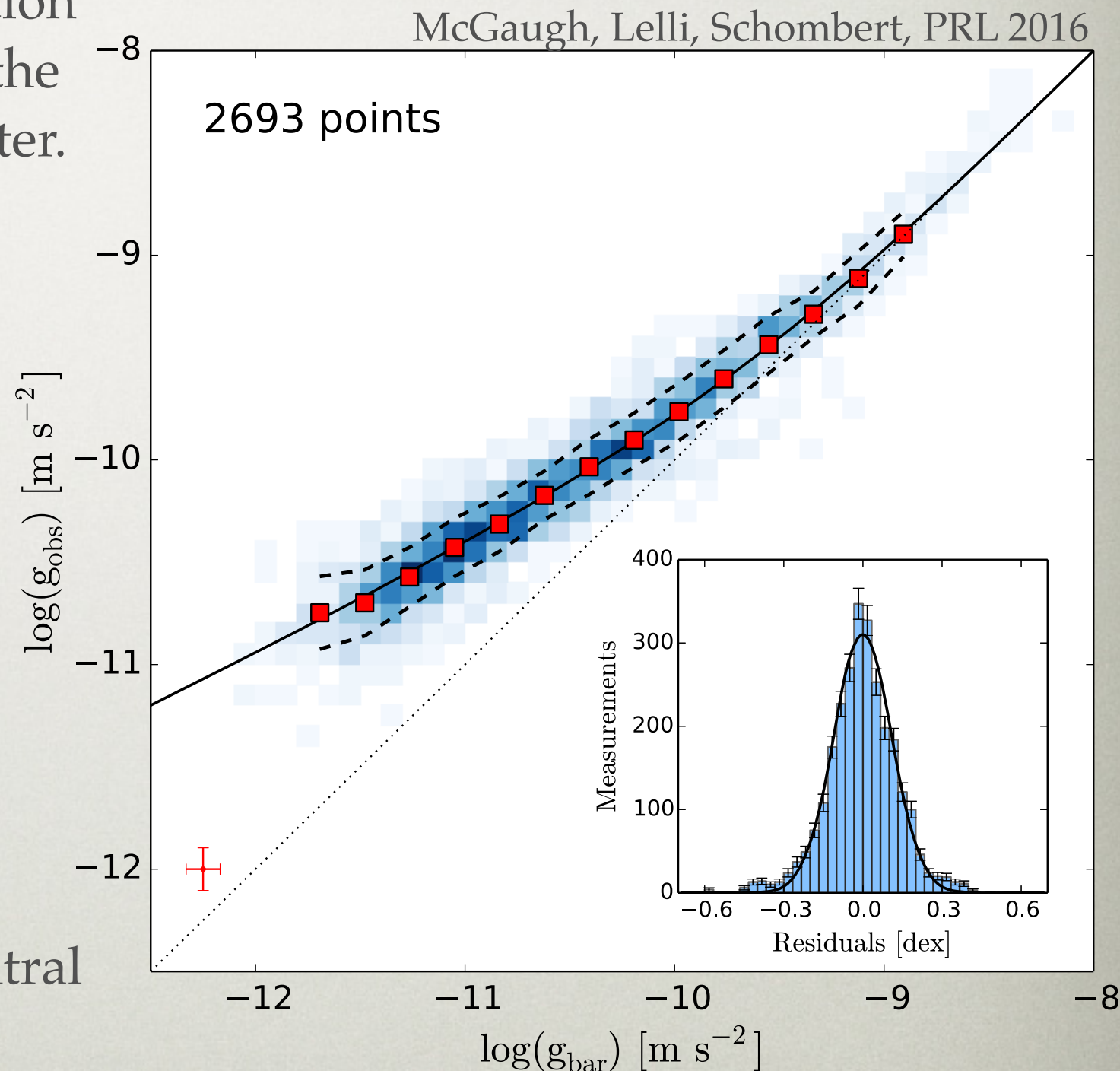
Derived from 153 of the 175 SPARC galaxies.

The correlation can be described by:

$$a_{\text{obs}} = \frac{a_{\text{bar}}}{1 - e^{-\sqrt{a_{\text{bar}}/a_0}}}$$

with $a_0 = 1.20 \times 10^{-13} \text{ km/s}^2$.

Therefore, a_0 is distributed around a central value.

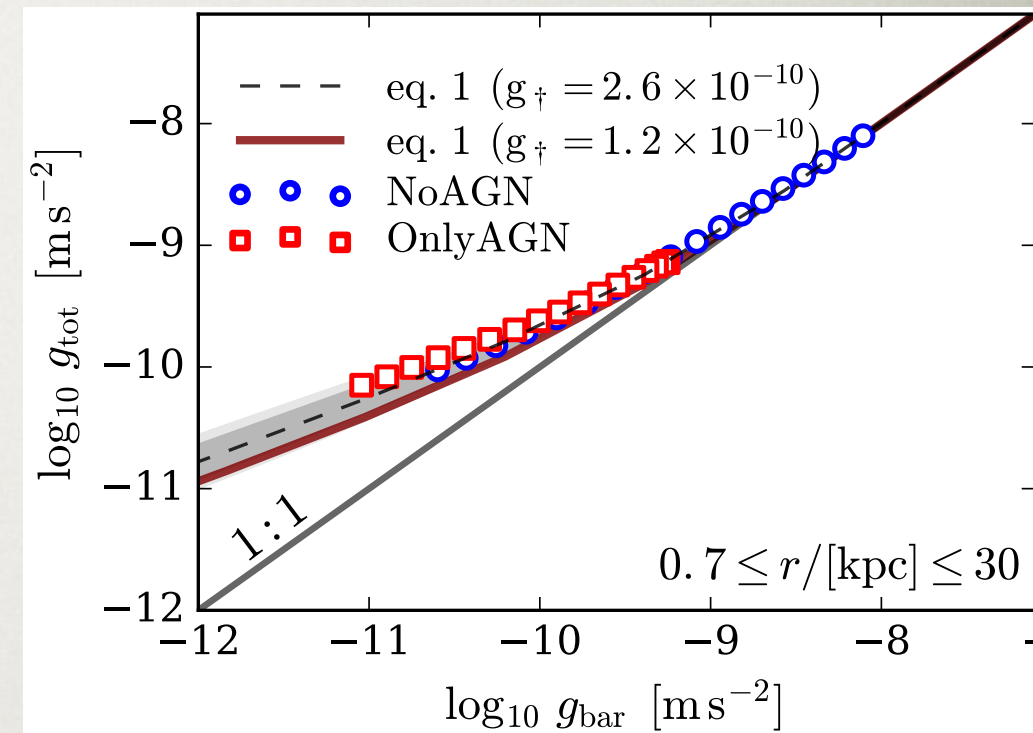


Fundamental acceleration scale?

The RAR could be the result of

1. complex interplay between dark matter and baryons: **emergent nature**
2. modified theory of gravity, which reduces to MOND at the scale of galaxies: **fundamental nature**

Ludlow et al PRL 2017



Fundamental acceleration scale?

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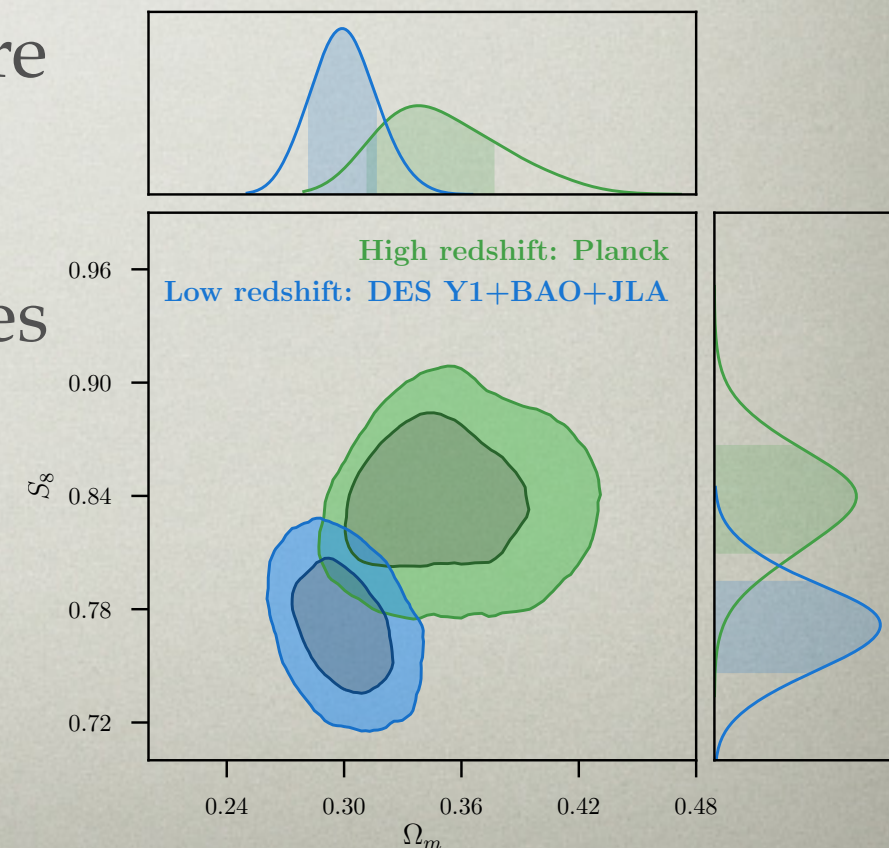
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The basic idea is that in order to understand the nature of a_0 one has to:

1. compute the posterior on a_0 for the SPARC galaxies
2. see if the posteriors are compatibles



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MAGMA

Mathematica Automatized Galaxy Mass Analysis

github.com/davi-rodrigues/MAGMA



mBayes

Bayesian inference with Mathematica

github.com/valerio-marra/mBayes



Credible intervals on a_0

Codes to automatically analyse hundreds of galaxies

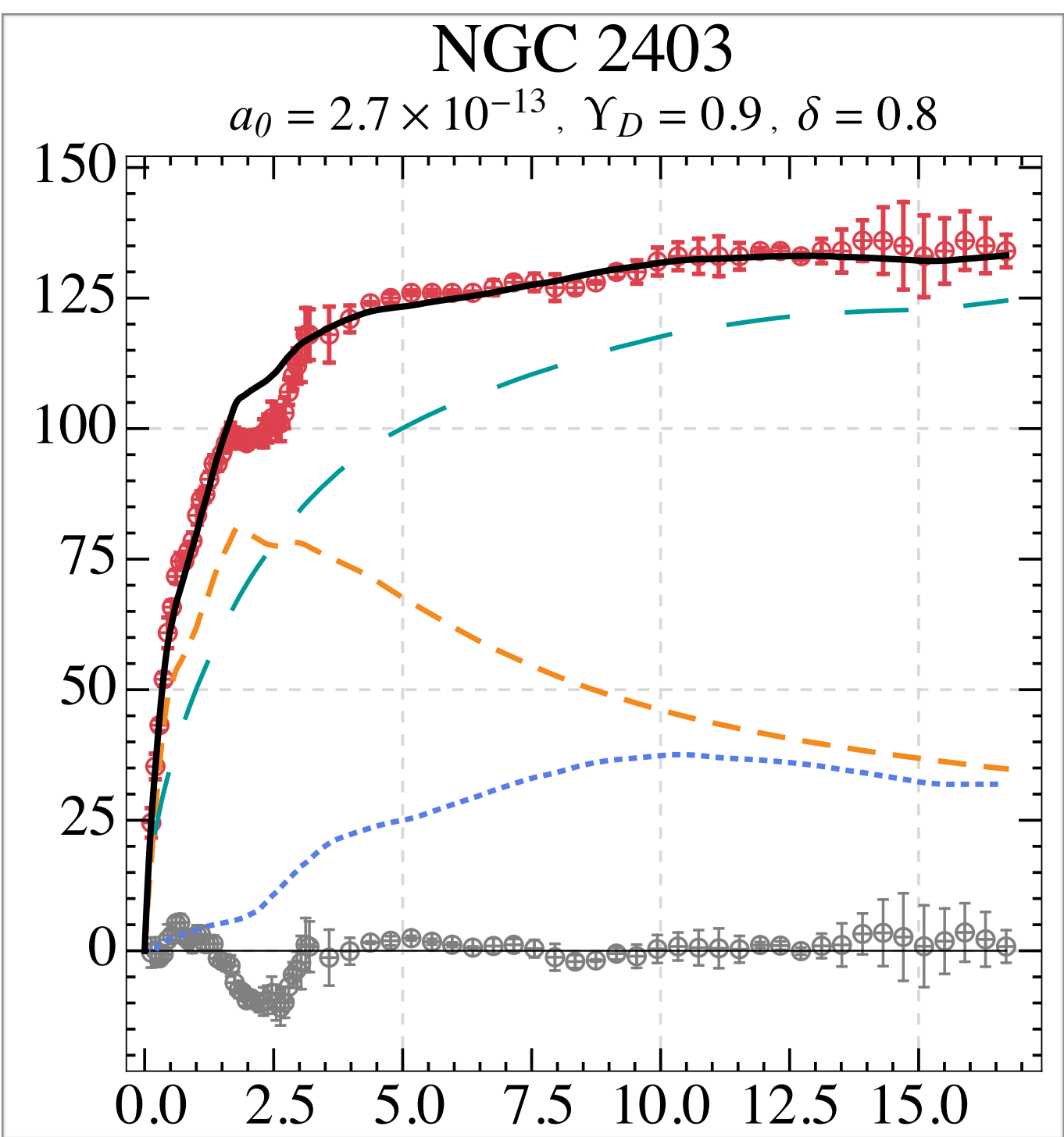
MAGMA

Math

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MAGMAfit["MONDsimple", "FaG  
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- UGC10310-
- UGC09992-
- UGC09133-
- UGC09037-
- UGC08837-
- UGC08699-
- UGC08550-
- UGC08490-
- UGC08286-
- UGC07866-
- UGC07690-



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MAPlots

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Can be found at Github: <https://github.com/davi-rodrigues/MAGMA>

mBayes

Bayesian inference with Wolfram Mathematica

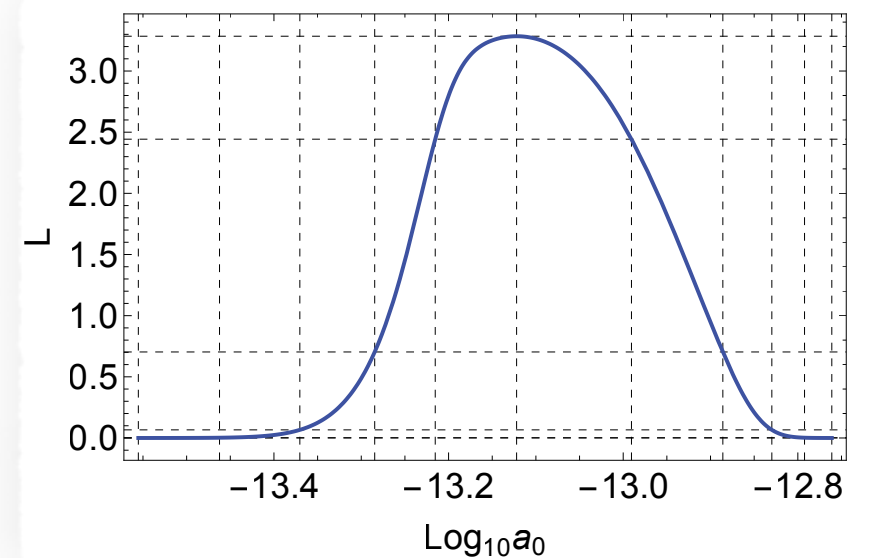
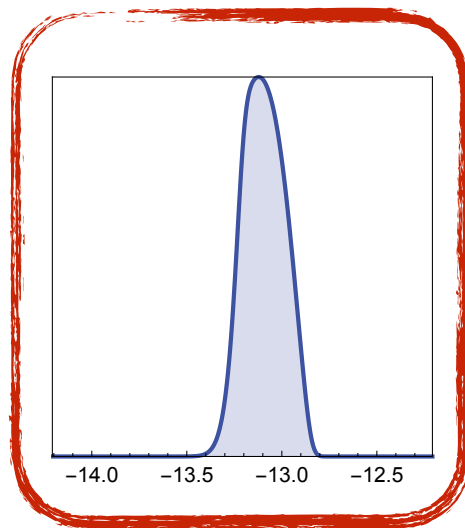
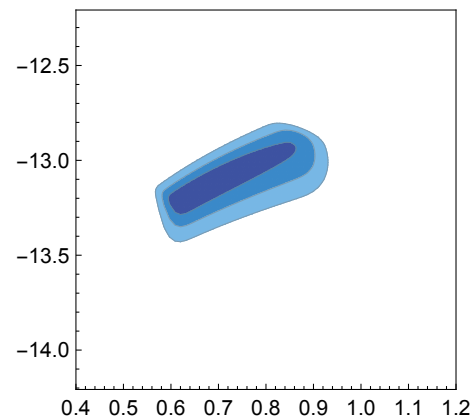
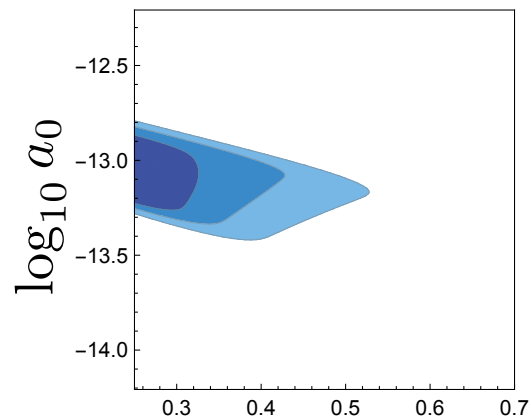
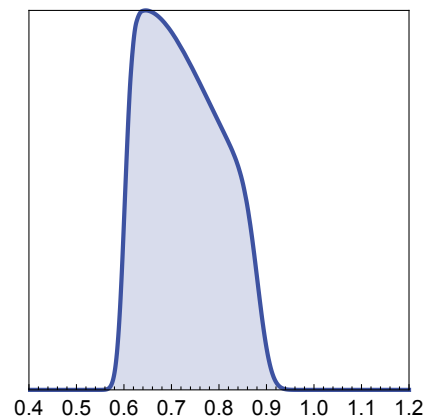
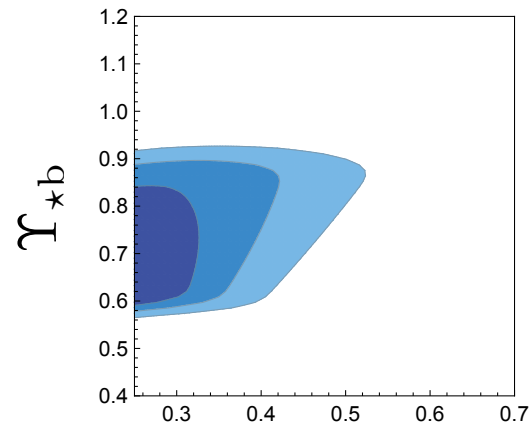
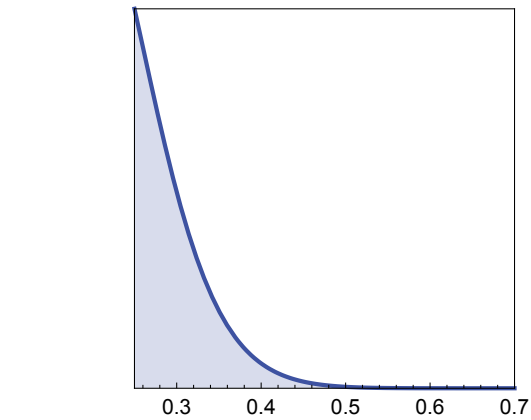
NGC6195

Posterior on a_0

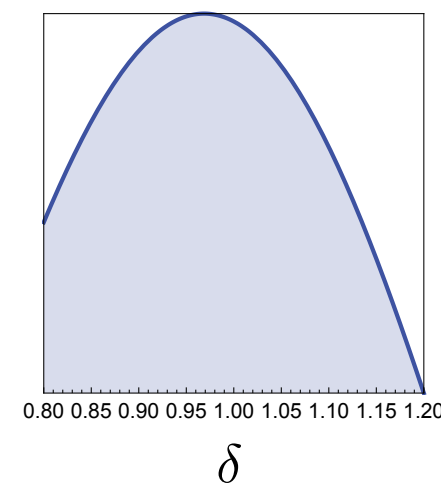
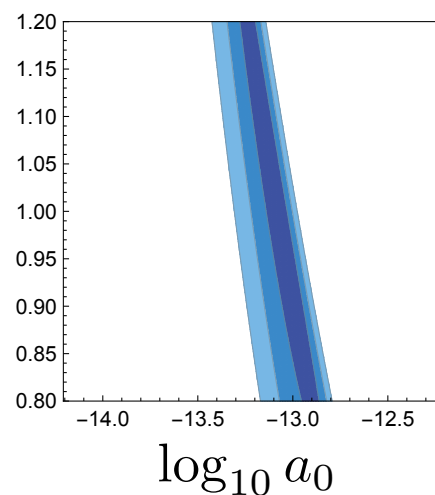
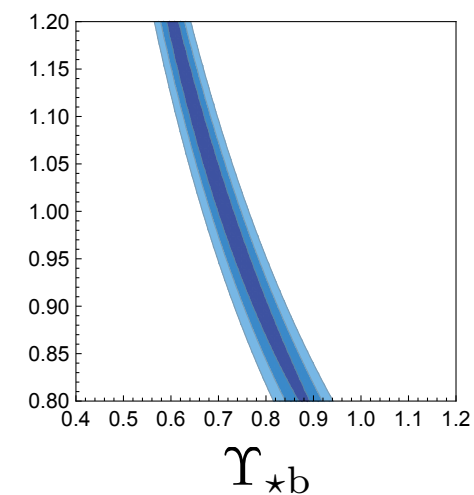
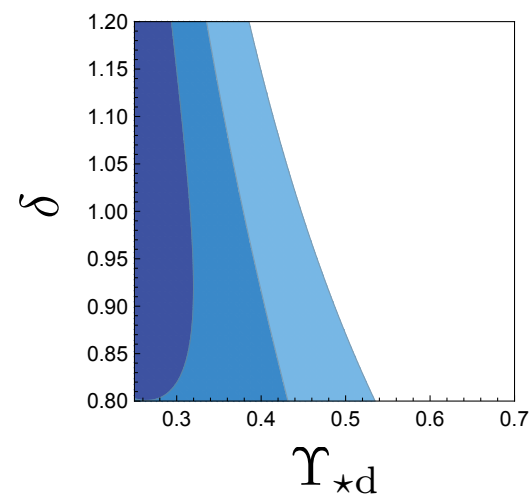
1-to-5 σ intervals

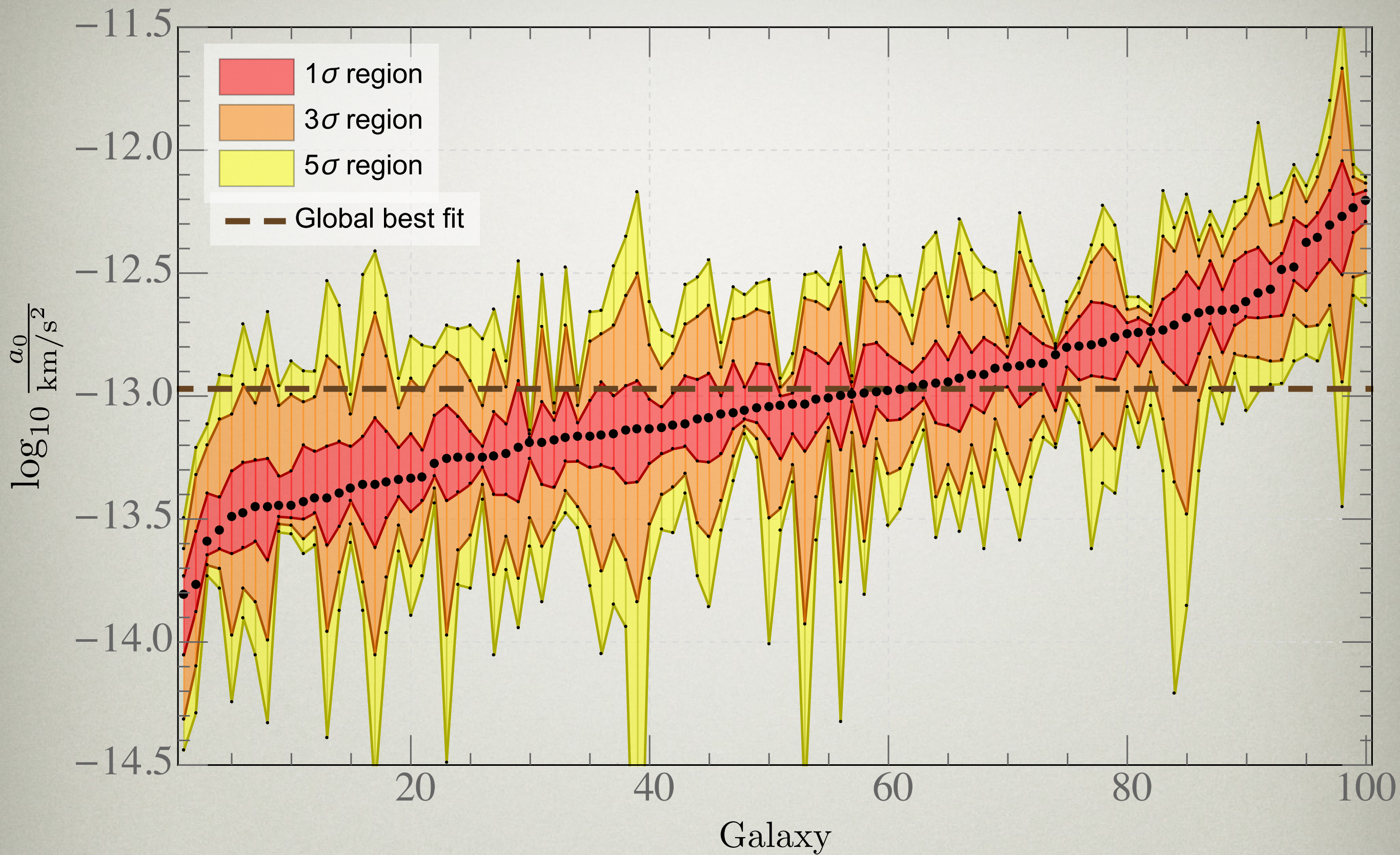
x 175 x 3

mass-to-light ratio



distance variation





100 of the 175 SPARC galaxies that passed the quality cuts

Significance

$$\bar{a}_{0,j} = \int da_0 a_0 f_j(a_0) ,$$

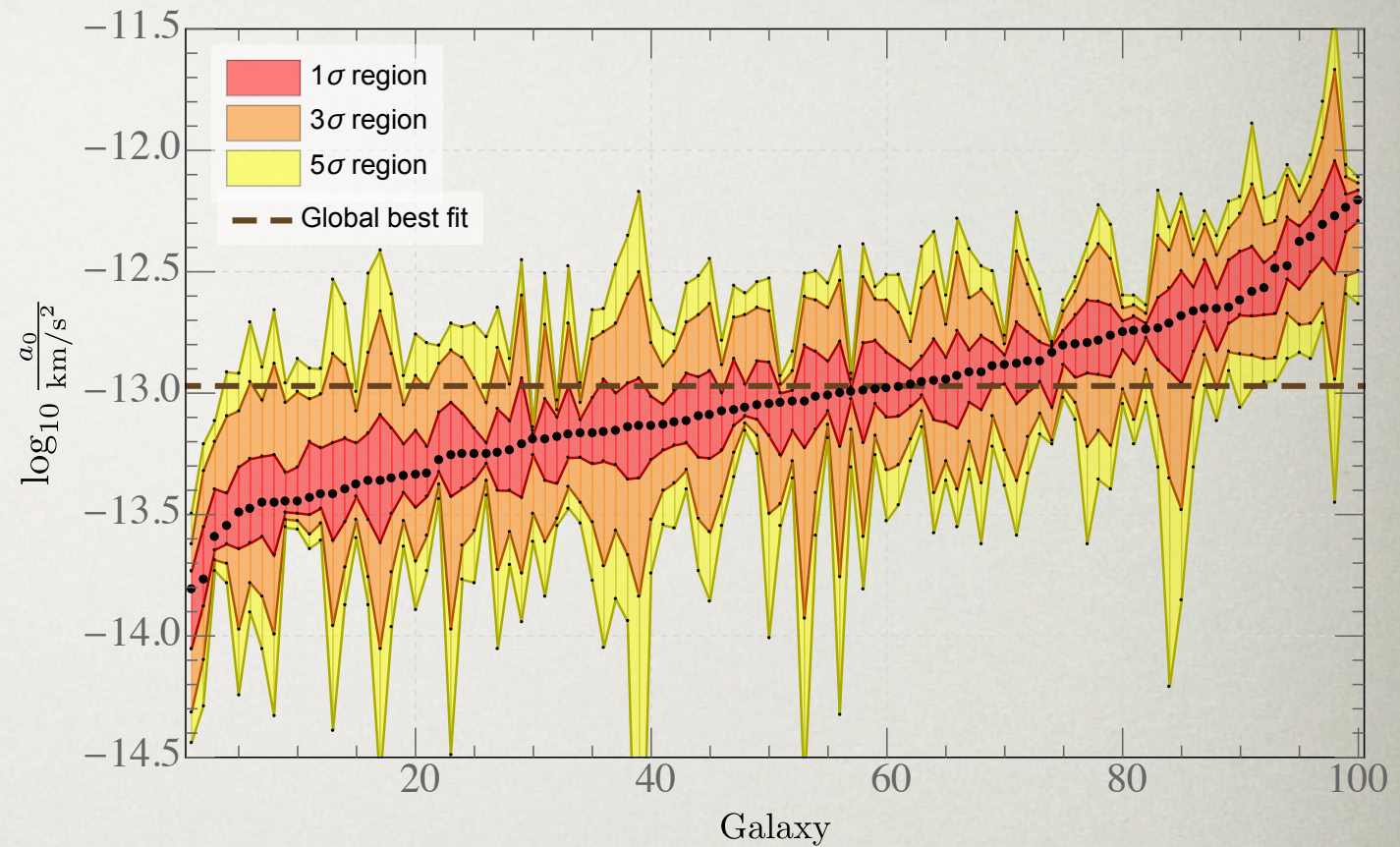
$$\sigma_{a,j}^2 = \int da_0 (a_0 - \bar{a}_{0,j})^2 f_j(a_0) ,$$

$$\chi^2(a_0) = \sum_{j=1}^N \frac{(\bar{a}_{0,j} - a_0)^2}{\sigma_{a,j}^2} ,$$

which is minimized by the global best fit.

The null hypothesis that a common acceleration scale exists is then rejected at:

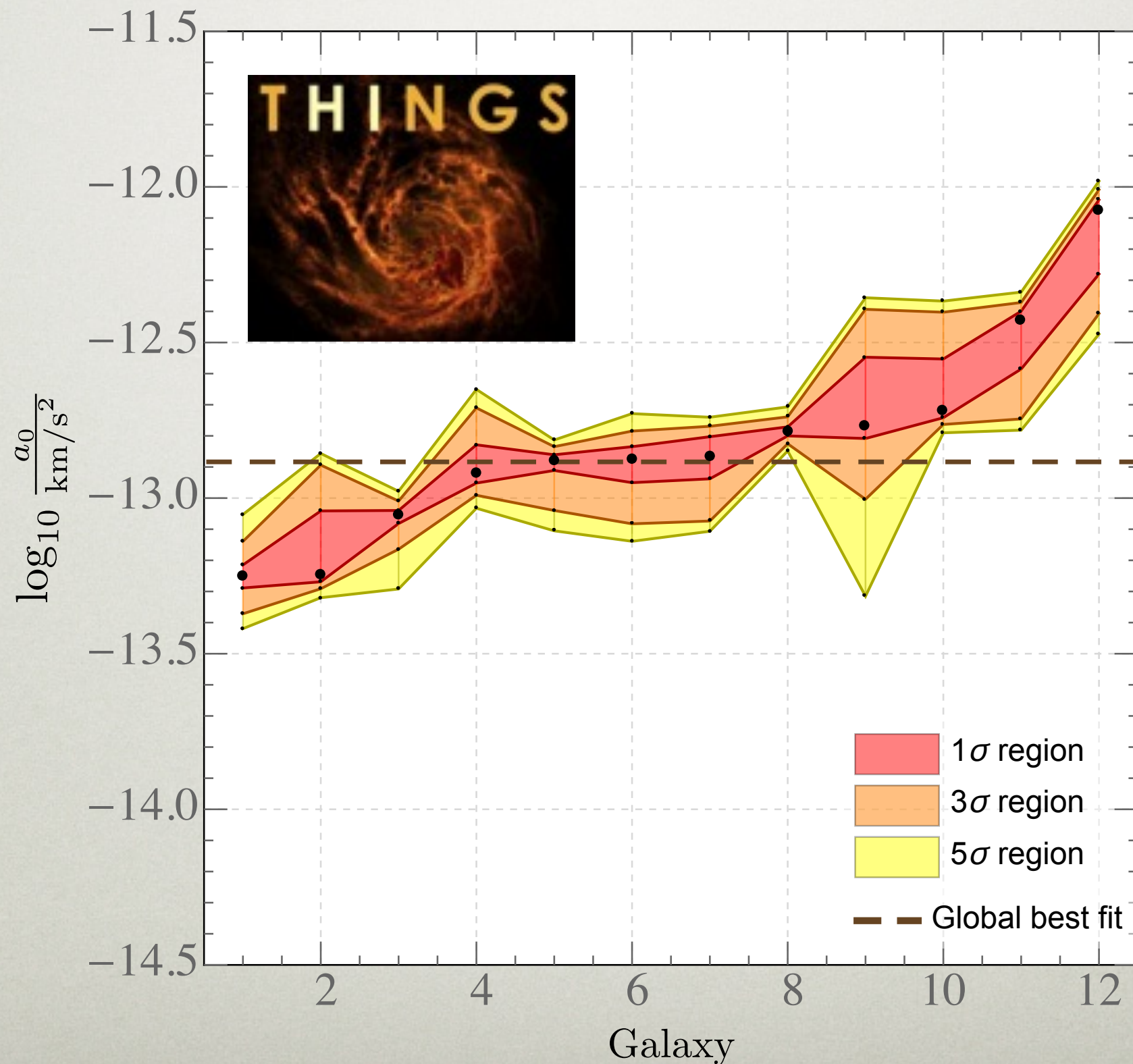
$$n_\sigma = \frac{\chi^2(a_0^{\text{bf}}) - k}{\sqrt{2k}}$$



For the case above we find:

$$n_\sigma \sim 50$$

Using the THINGS sample



Conclusions

Using the very (SPARC) data that showed via the RAR the existence of a "common" acceleration scale in galaxies, we showed that this scale is emergent and not fundamental.

Hence, MOND, or any other theory that behaves like it at galactic scales, is ruled out as a fundamental theory for galaxies with high significance.

obrigado