Clustering scale of dark matter

Łukasz Bratek, Joanna Jałocha,
Marcin Kolonko, Marek Kutschera, Piotr Skindzier

Department of Theoretical Astrophysics
Institute of Nuclear Physics, Krakow, Poland

Cracow School of Theoretical Physics XLVII Course Zakopane, 16/6/2007

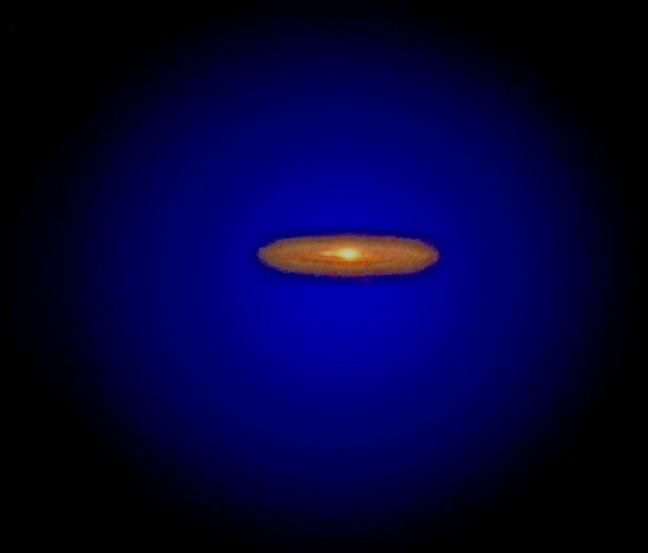
Where is the alleged Dark Matter ?

The Concordance Lambda Cold Dark Matter Cosmological Model predicts that

22% of total energy in the Universe is in the form of Nonbaryonic Dark Matter.

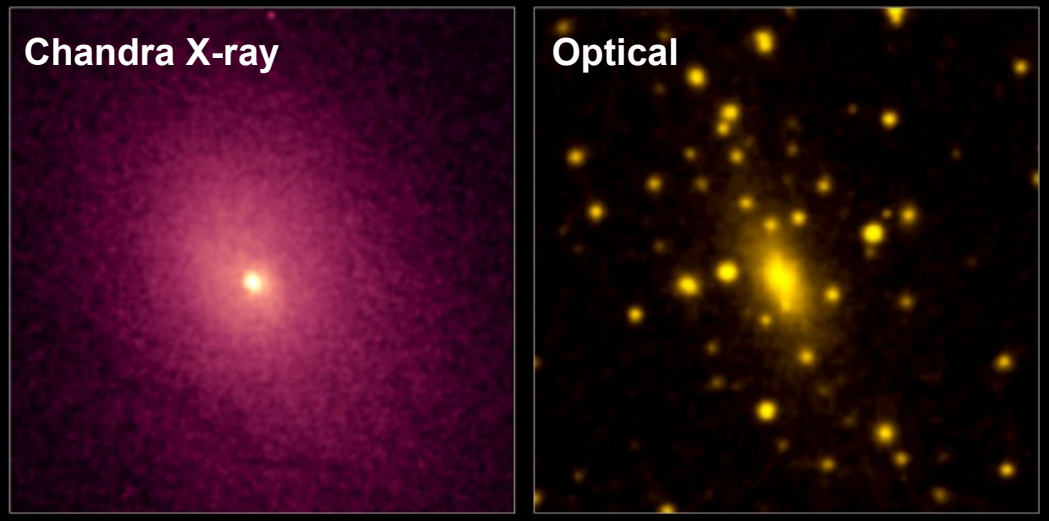
If so, how is dark matter distributed and what is its clustering scale?

Small clustering scale
high local density of DM



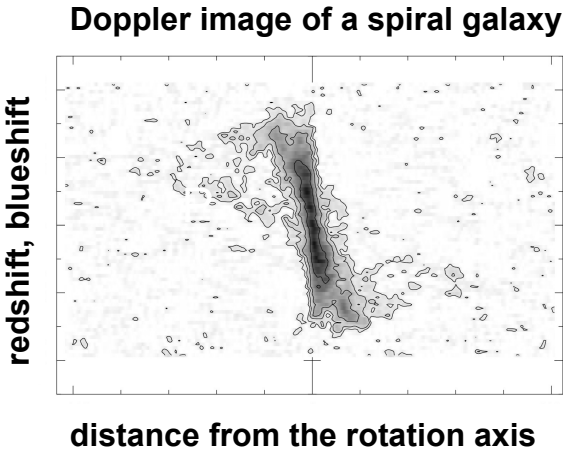
spherical halo of dark matter surrounding a spiral galaxy

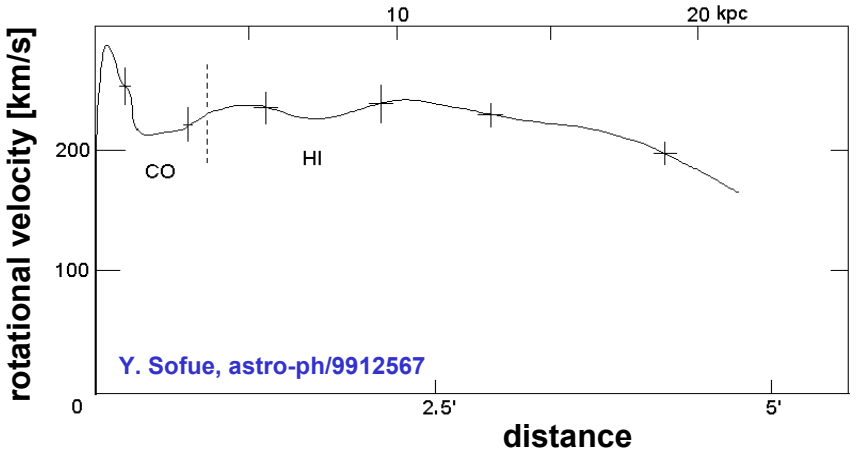
Large clustering scale
low local density of DM



thousands of galaxies enveloped in a gigantic cloud of hot gas and confined to the Abell 2029 cluster by the gravity of dark matter

Rotation curves of spiral galaxies and Dark Matter (DM)

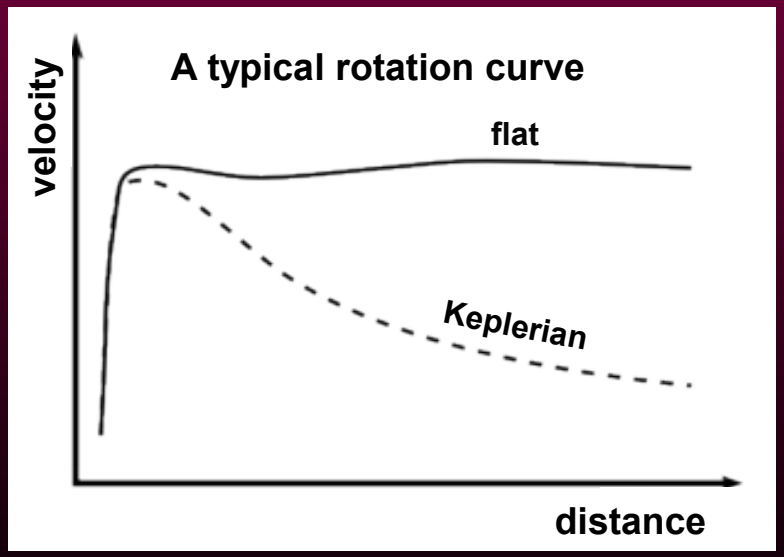




Problems:

- flat rotation curves, not Keplerian
- dynamical mass different from the mass of visible matter
- the Infra Red band mass-to-light ratio M/L should be not greater than 2, otherwise dark matter is required

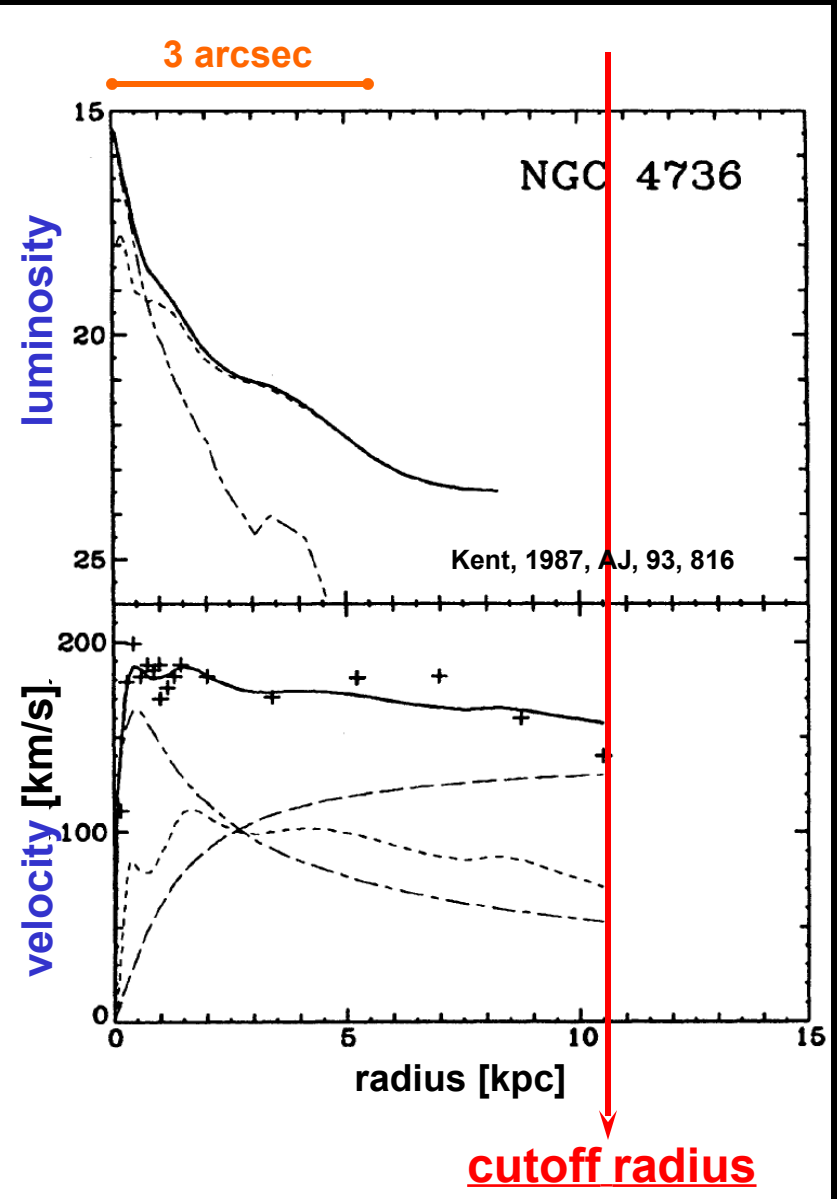
(M/L=1 for the Sun)



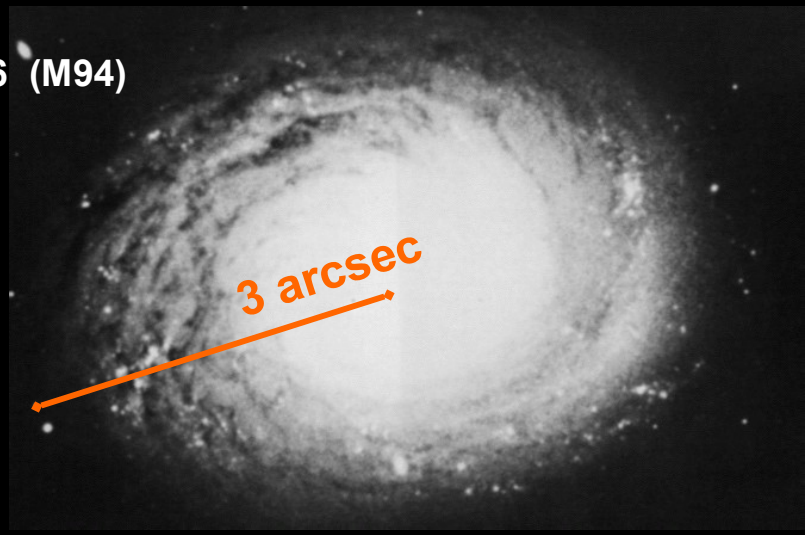
Standard modelling of rotation curves:

arbitrarily assumes a spherical halo of DM inside of which the luminous baryonic matter with a constant M/L is immersed

standard modelling of rotation curves



NGC 4736 (M94)



Standard approach:

input: *luminosity profile*

1. luminosity profile decomposition : central bulge + disk
2. mass densities assumed proportional to luminosities
3. the missing mass added in the form of the spherical dark halo

output: *constant mass-to-light ratios*
& *the amount of missing mass*

Our approach: (reduces the amount of dark matter)

input: *rotation curve + mass distribution outside the cutoff radius*

1. Global Disk Model + Iterative Spectral Method

output: *the global mass distribution*
(in perfect agreement with rotation curve)
& *the mass-to-luminosity ratio profile*

Global Disk Model of (disk-like) spiral galaxies:

infinitely thin layer of dust rotating on circular concentric orbits

(in the framework of Newtonian gravitation)

axial and reflection symmetry, cylindrical coordinates

$$\triangle\Phi = 0 \quad \Rightarrow \quad \Phi(\rho,z) = -\int_0^\infty C(\lambda) J_0(\lambda\rho) e^{-\lambda|z|} \mathrm{d}\lambda, \quad z \neq 0$$

$$\sigma(\rho) = \frac{1}{2\pi G}\partial_z \Phi|_{z=0} \quad \Rightarrow \quad \sigma(\rho) = \frac{1}{2\pi G}\int_0^\infty \lambda C(\lambda) J_0(\lambda\rho)\mathrm{d}\lambda$$

$$\frac{v^2(\rho)}{\rho} = \partial_\rho \Phi|_{z=0} \quad \Rightarrow \quad \frac{v^2(\rho)}{\rho} = \int_0^\infty \lambda C(\lambda) J_1(\lambda\rho)\mathrm{d}\lambda$$

spectral decomposition of rotation curve

$$x := \frac{\rho}{R}, \qquad u(x) := \frac{v(Rx)}{v(R)}, \qquad x \in (0,1)$$

$$\frac{u^2(x)}{x} = \sum_k \sigma_k J_1(\omega_k x), \qquad J_0(\omega_k) = 0$$

$$\sigma_k = \frac{2}{J_1(\omega_k)} \int_0^1 u^2(x) \frac{J_1(\omega_k x)}{J_1(\omega_k)} \mathrm{d}x$$

approximation of the surface mass density

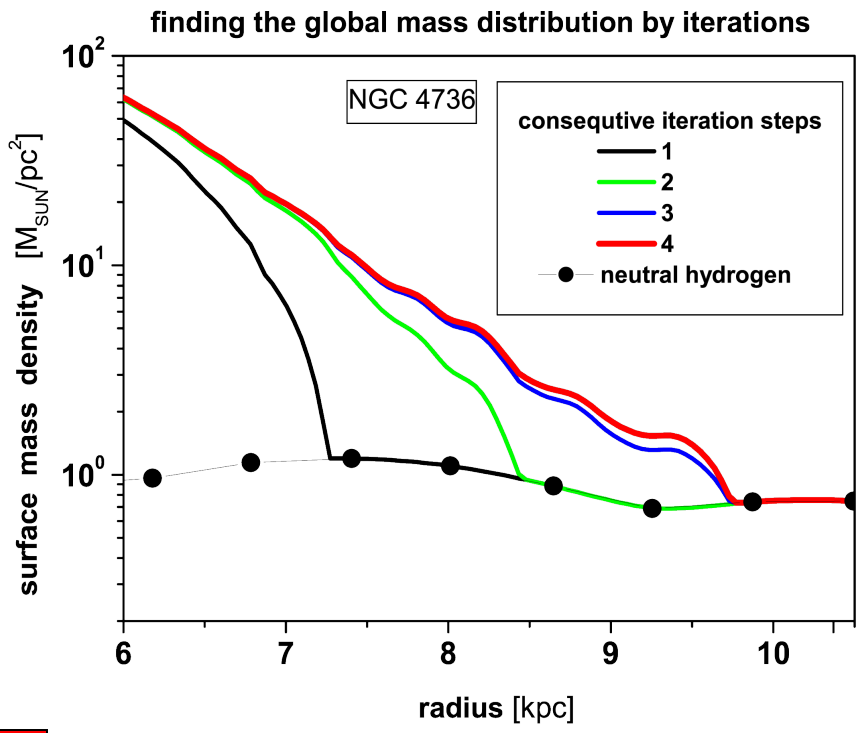
$$\sigma(\rho) \approx \frac{v^2(R)}{2\pi G R} \cdot \sum_k \sigma_k J_0\left(\omega_k \frac{\rho}{R}\right), \qquad \rho < R$$

$$v^2(\rho) = 4G\rho \cdot \mathrm{V.p.} \left(\int_0^\rho \sigma(\chi) \frac{\chi E\left(\frac{\chi}{\rho}\right)}{\rho^2 - \chi^2} \mathrm{d}\chi - \int_\rho^\infty \sigma(\chi) \left[\frac{\chi^2 E\left(\frac{\rho}{\chi}\right)}{\rho\left(\chi^2 - \rho^2\right)} - \frac{K\left(\frac{\rho}{\chi}\right)}{\rho} \right] \mathrm{d}\chi \right)$$

$$\sigma(\rho) = \frac{1}{\pi^2 G} \cdot \mathrm{V.p.} \left(\int_0^\rho v^2(\chi) \left[\frac{K\left(\frac{\chi}{\rho}\right)}{\rho\,\chi} - \frac{\rho}{\chi} \frac{E\left(\frac{\chi}{\rho}\right)}{\rho^2 - \chi^2} \right] \mathrm{d}\chi + \int_\rho^\infty v^2(\chi) \frac{E\left(\frac{\rho}{\chi}\right)}{\chi^2 - \rho^2} \mathrm{d}\chi \right)$$

convergence through iterations

rotation curves are not enough,
for completeness, additional data required:
e.g. hydrogen distribution in the remotest regions



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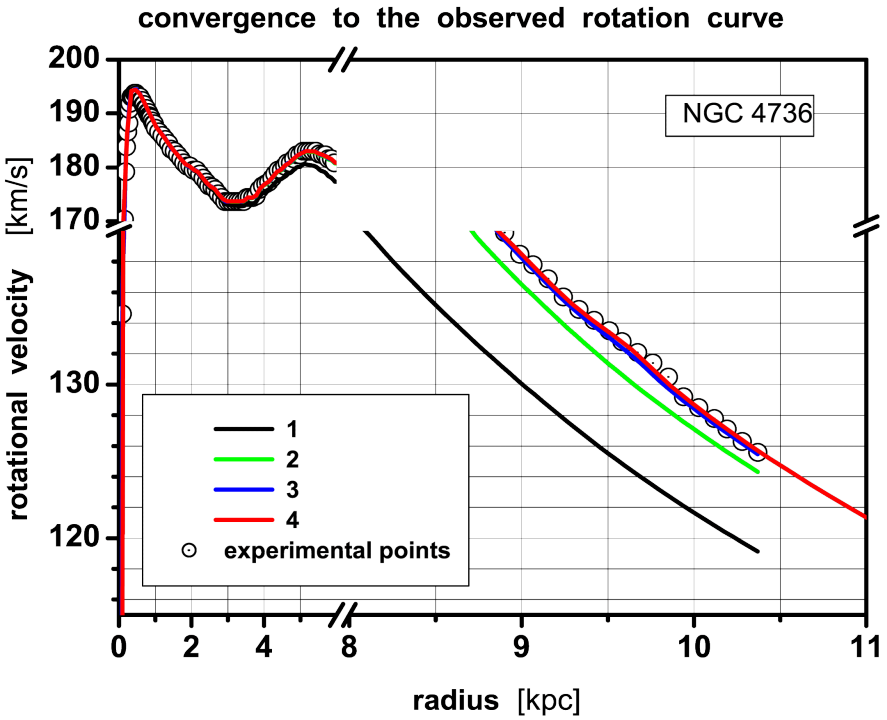
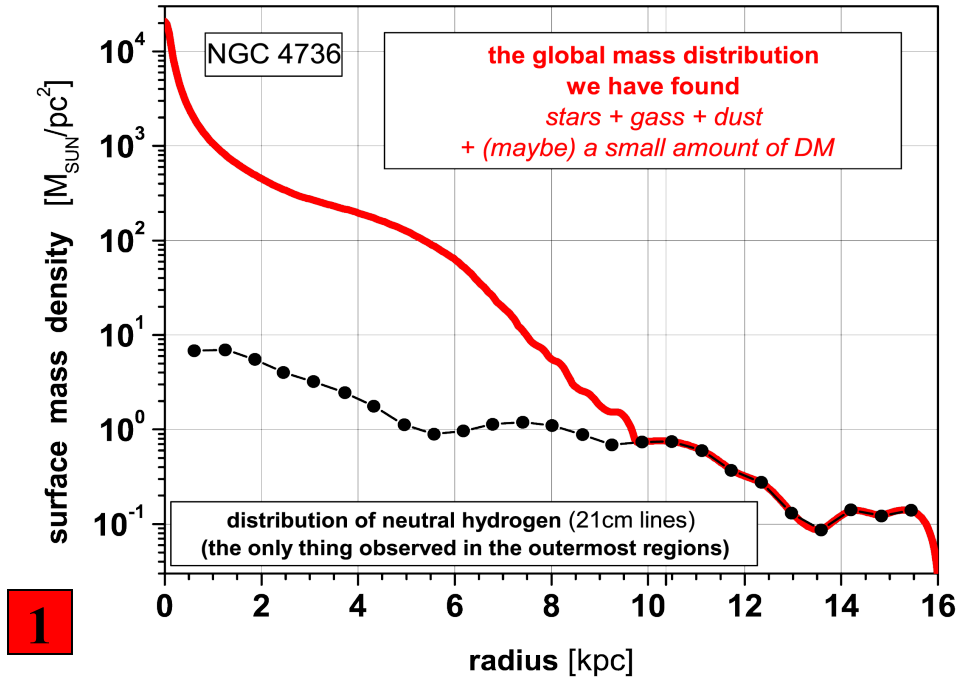
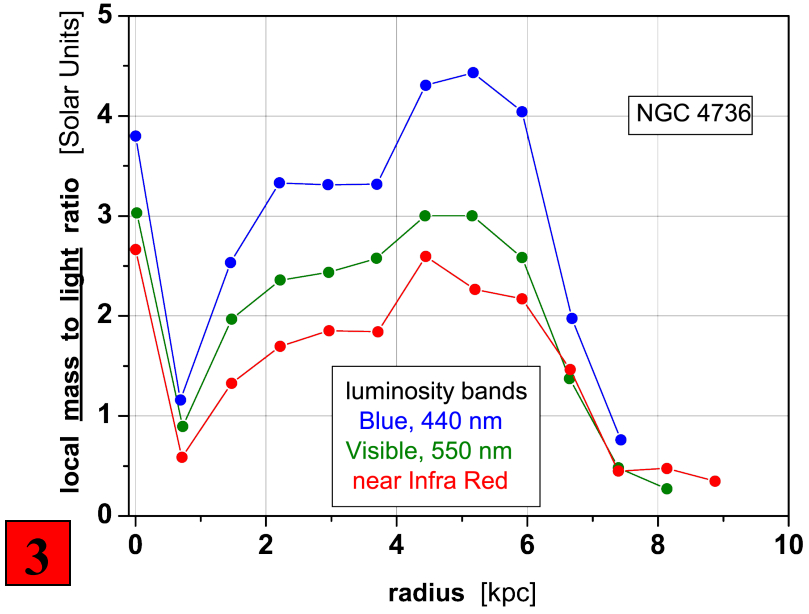
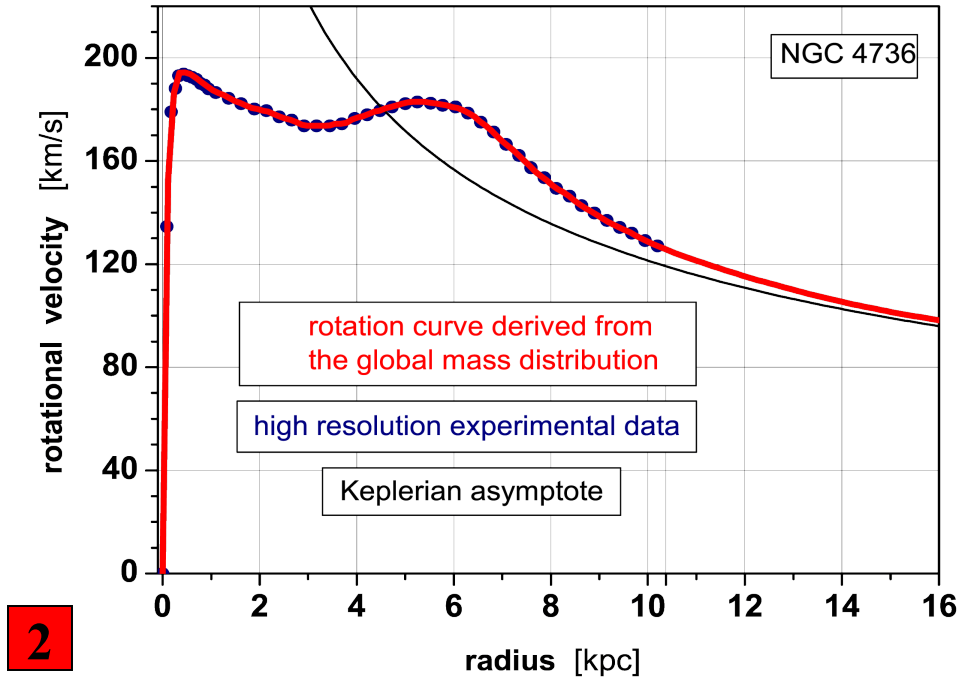


2

A SAMPLE OF OUR RESULTS







the total mass: 34 milliards of Solar masses
the global IR-band mass-to-light ratio: 1.2 in Solar units

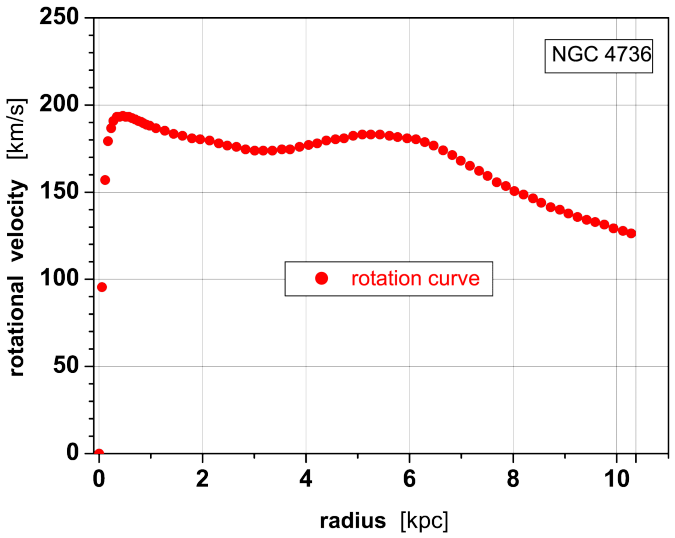
Spherical halo model:

problems in fitting their model to observations
2/3 of total mass of the galaxy in the form of Dark Matter

Disk model:

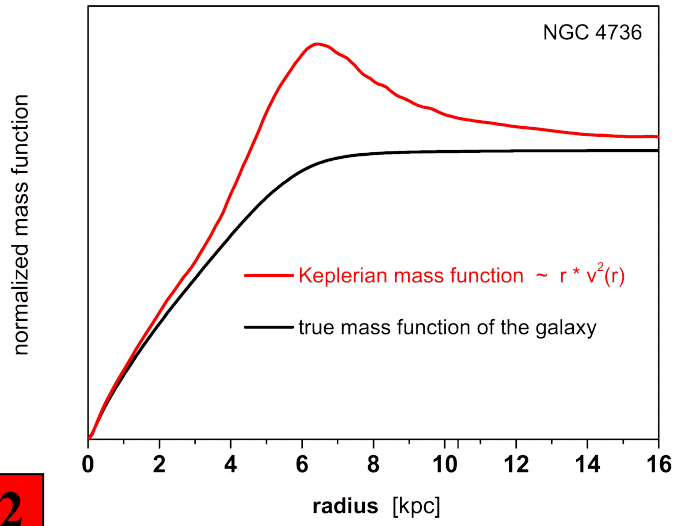
a consistent global mass distribution,
excellent reconstruction of rotation curve
Dark Matter?, maybe some

Not all galaxies are dominated by spherical mass distribution



1

sphericity test



2

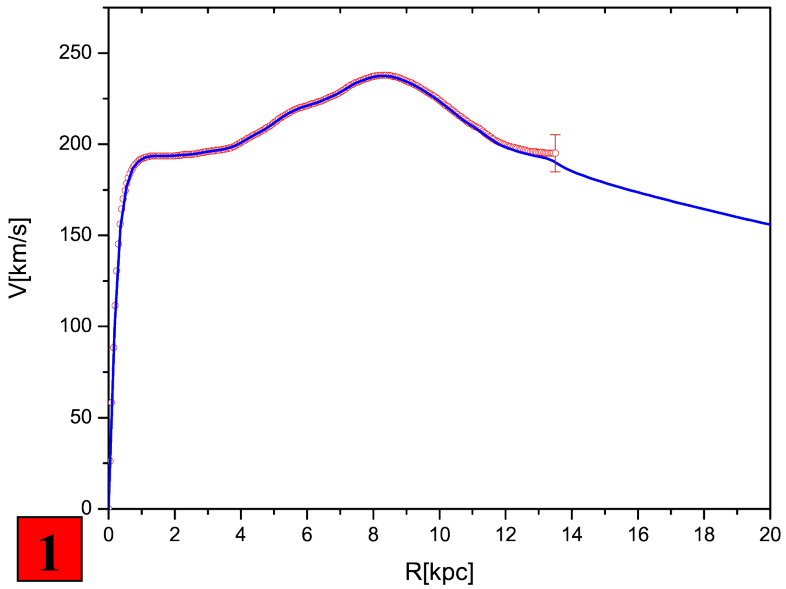
the global disk model can be applied to these galaxies

rotation curves of many disk-like objects satisfy the sphericity condition, e.g.

$$\sigma(x) = \frac{1}{2\pi\left(1+x^2\right)^{3/2}}, \quad V(x) = \frac{x}{\left(1+x^2\right)^{3/4}}, \quad d_x\left(xV^2(x)\right) = \frac{3x^2}{\left(1+x^2\right)^{5/2}} > 0$$

Example - M101

The test of sphericity of matter distribution implies that there is no dominance of spherical component.



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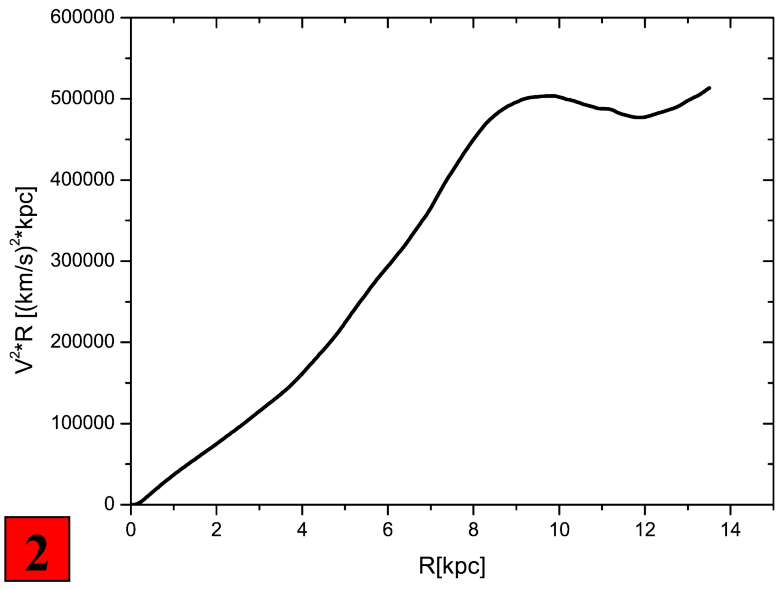
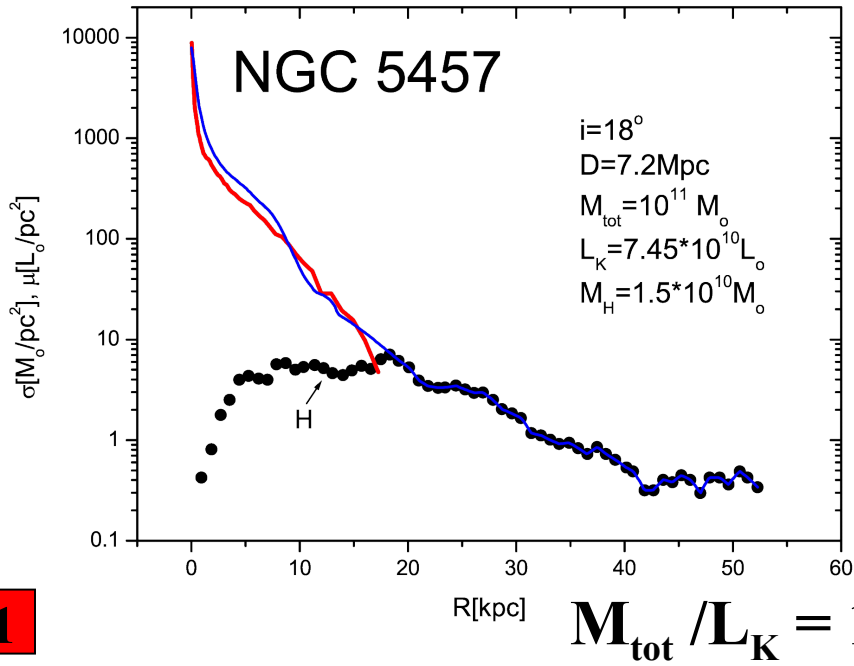


2

M101 – continued

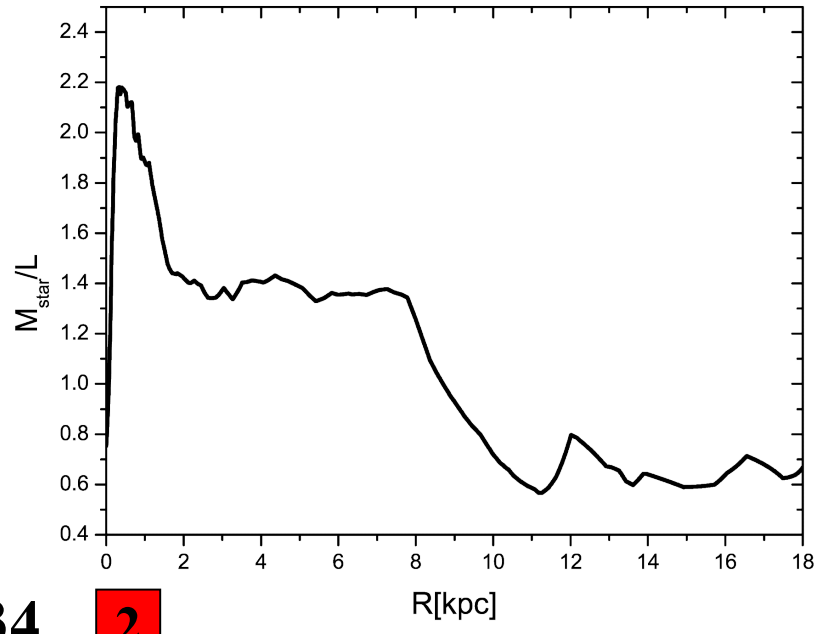
The neutral hydrogen (dots), total mass distribution (blue line) and luminosity in the K band (red line).

The mass-to-light ratio does not vary much and is low.



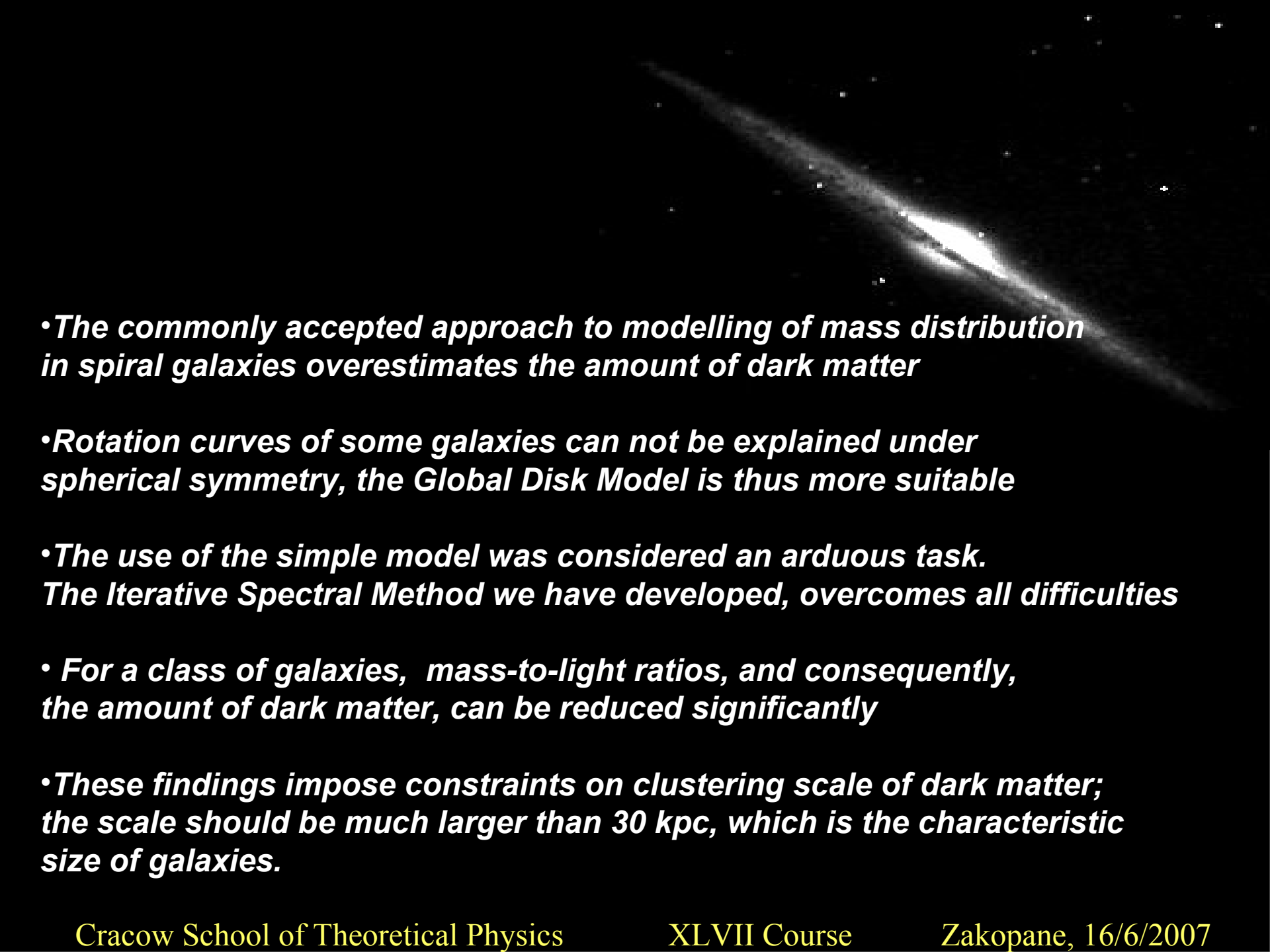
1

$M_{tot}/L_K = 1.34$



2

Thus **NGC 5457** is also a galaxy which does not need DM (Dark Matter) to explain its rotation curve.



- *The commonly accepted approach to modelling of mass distribution in spiral galaxies overestimates the amount of dark matter*

- *Rotation curves of some galaxies can not be explained under spherical symmetry, the Global Disk Model is thus more suitable*

- *The use of the simple model was considered an arduous task. The Iterative Spectral Method we have developed, overcomes all difficulties*

- *For a class of galaxies, mass-to-light ratios, and consequently, the amount of dark matter, can be reduced significantly*

- *These findings impose constraints on clustering scale of dark matter; the scale should be much larger than 30 kpc, which is the characteristic size of galaxies.*