The

dark matter hypothesis

HISKP Colloquium
13.05.2014

based on Kroupa, 2012;
http://adsabs.harvard.edu/abs/2012PASA...29..395K

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To perform an academic exercise :

Can the standard model of cosmology be falsified?

Main mode of argumentation :
transposition in logics :

T => P <=> ~P => ~T ("~" = not)

(P <=> T is false,
because there may be a
T'≠ T
for which P => T' as well)

Prelude

Standard Model of Cosmology :
(the SMoC)

Postulate I : Einstein's field equation is valid everywhere

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + g_{\mu\nu} \Lambda = \frac{8\pi G}{c^4} T_{\mu\nu}$$

where $R_{\mu\nu}$ is the Ricci curvature tensor, R the scalar curvature, $g_{\mu\nu}$ the metric tensor, Λ is the cosmological constant, G is Newton's gravitational constant, c the speed of light in vacuum, and $T_{\mu\nu}$ the stress–energy tensor.

Postulate II : Matter is conserved

The SMoC

The model is immediately falsified :
- Prediction of a highly curved highly inhomogeneous universe

Solution:
- Postulate (III) a mathematical trick (*inflation*) not understood

This composite model is immediately falsified :
- Prediction of falling *rotation curves* of galaxies and *structure formation* too slow

Solution:
- Postulate (IV) existence of unknown exotic matter (*dark matter*) not found

This composite model is immediately falsified :
- Universe expands today faster, than it should

Solution: not understood
- Postulate (V) a mathematical trick (*dark energy*)

Problem ? :
- Model (=*Standard Model of Cosmology* = *LCDM*) does **not conserve energy ?** (Baryshev 2006)

End

of

Prelude

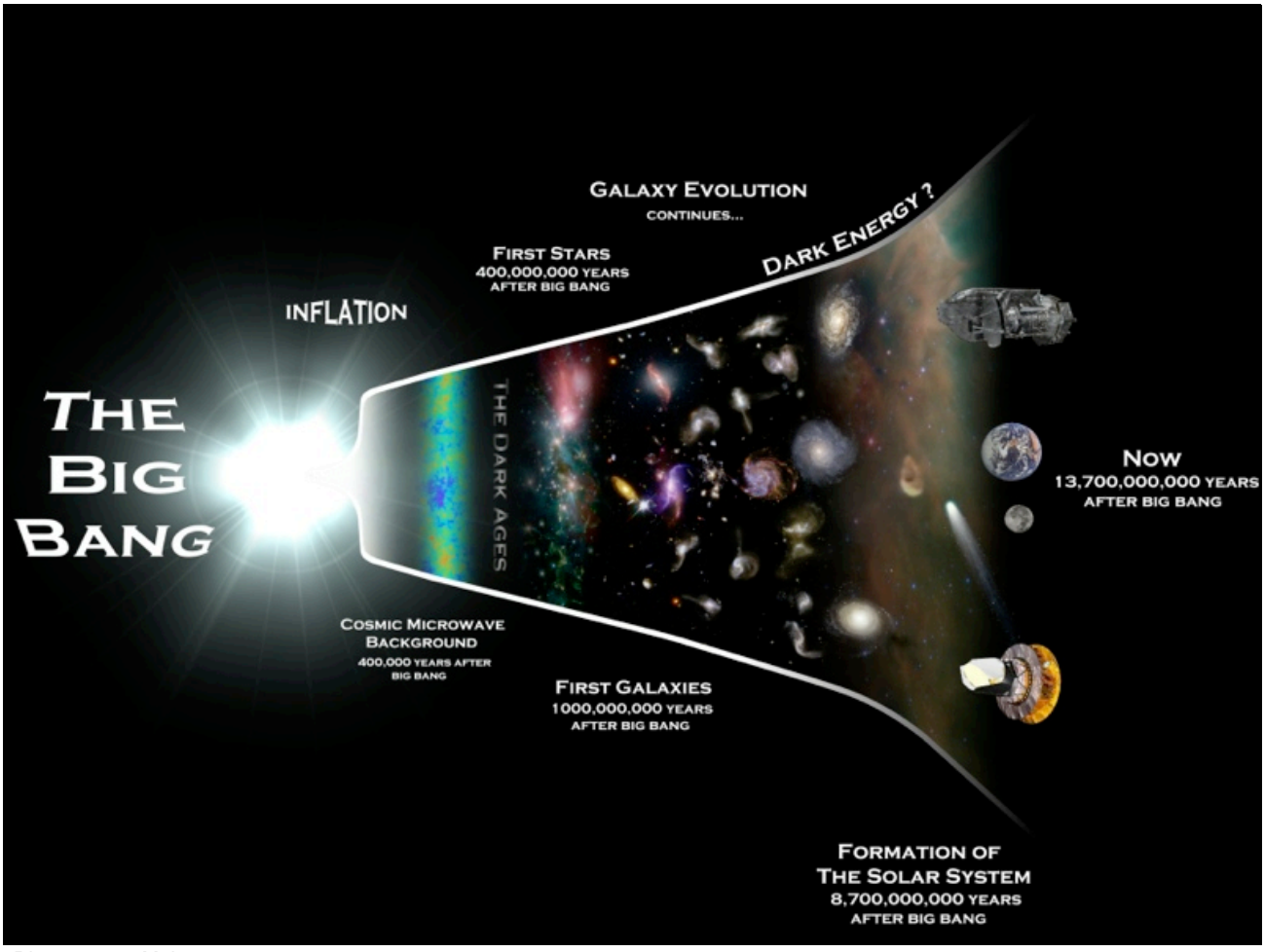
I was never against dark matter,

but when in 2010 I studied the SMoC
I had to conclude that it is the
positively worst theoretical construction
I have ever come across.

. . . but this statement does not
constitute a falsification of a model **!**

Assume **the standard model of cosmology (SMoC)**
is a valid description of the universe,

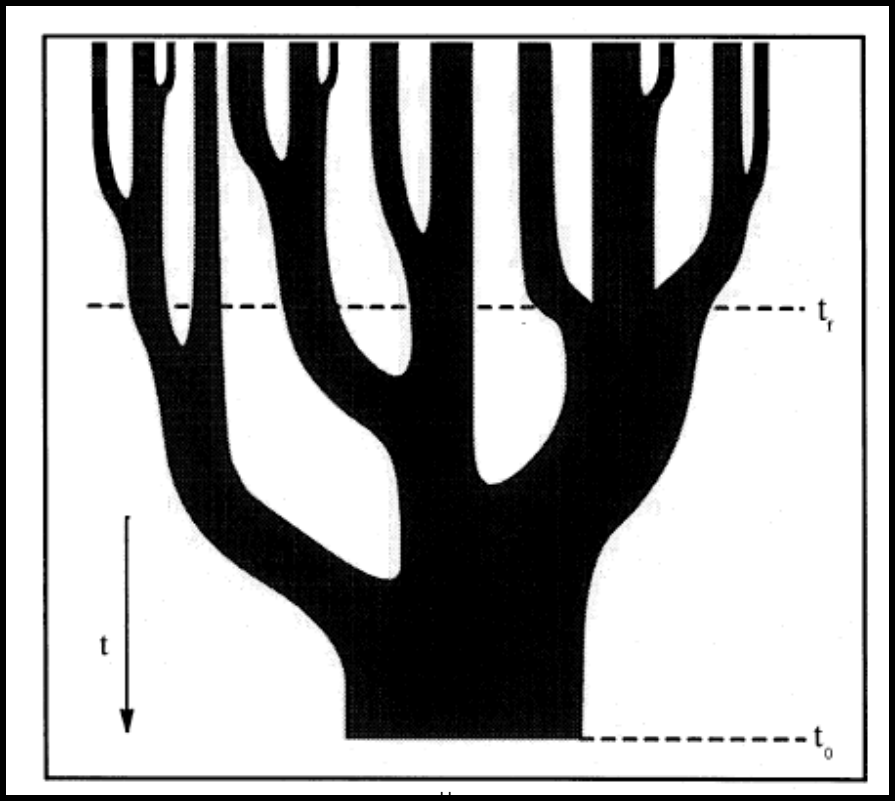
then test it where the data are of best quality . . .



Predictions

Consequence I

Structures form according to the cosmological merger tree

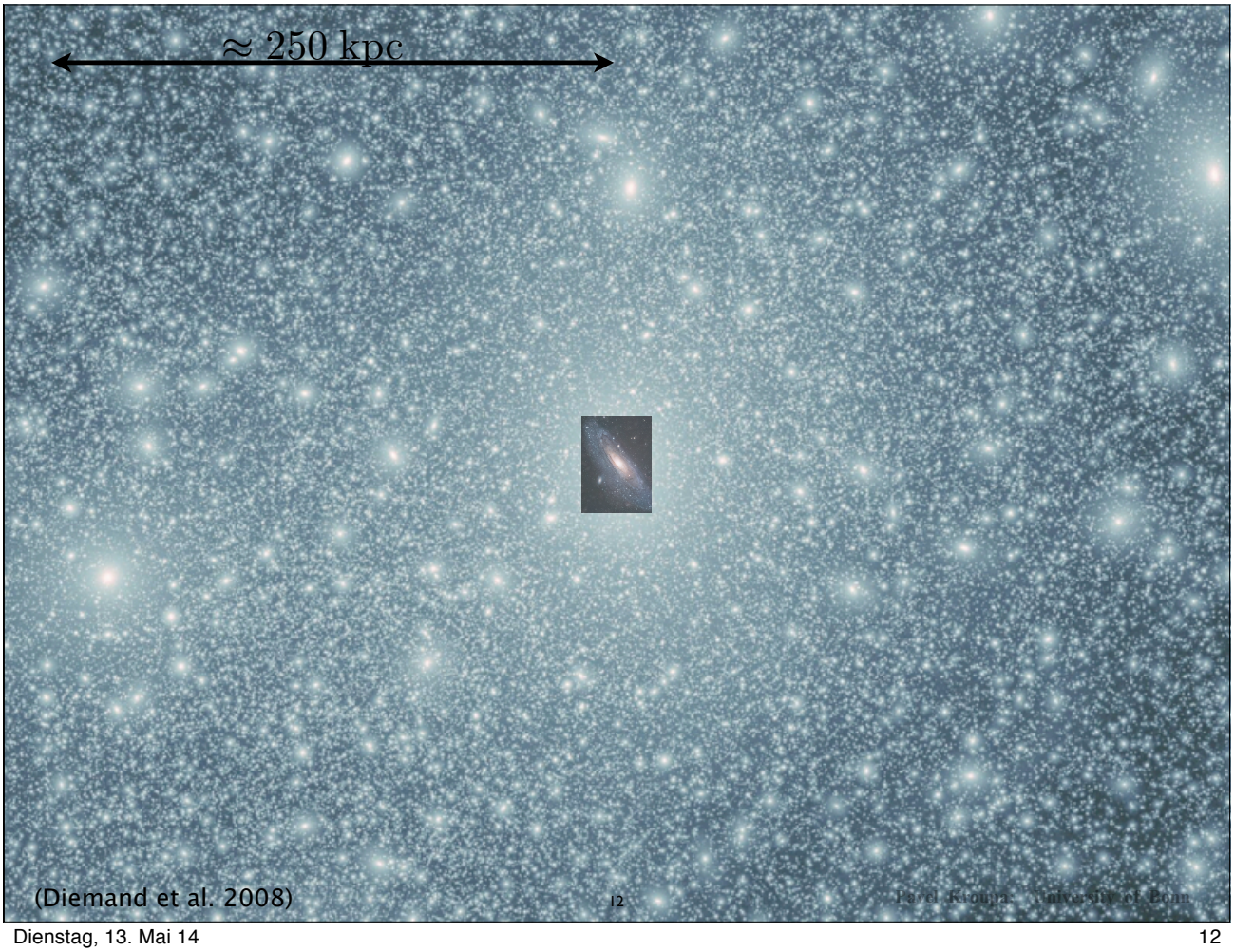


Lacey & Cole (1993)

the beginning Big Bang

DM sub-structures form first and coalesce to larger structures

today

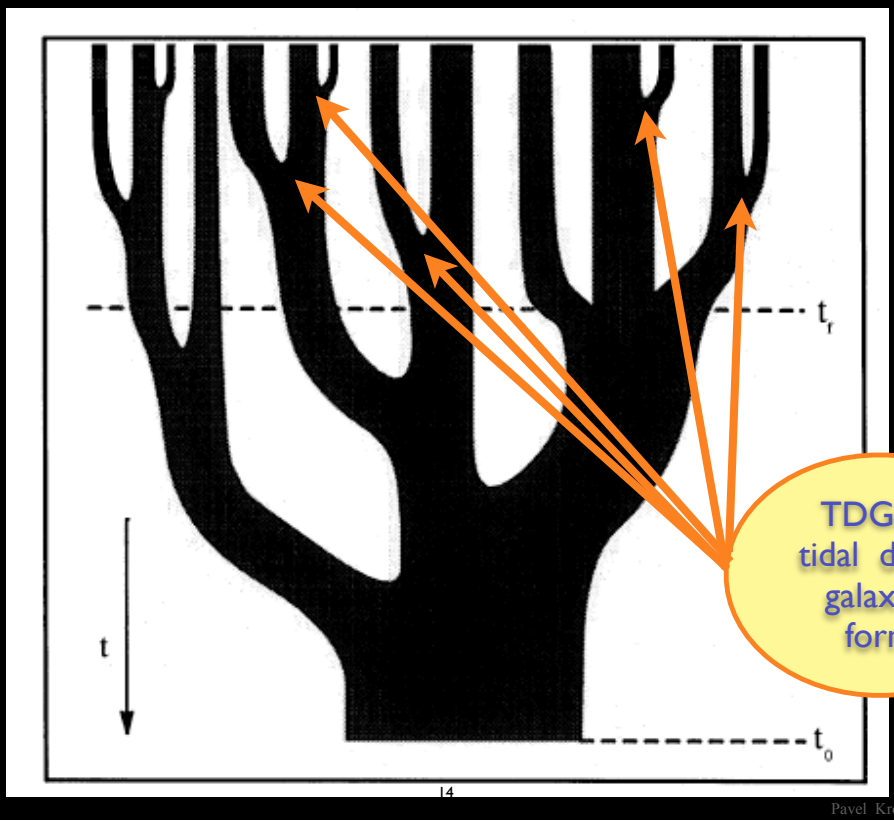


(Diemand et al. 2008)

Consequence II

Structures form according to the cosmological merger tree

Lacey & Cole (1993)



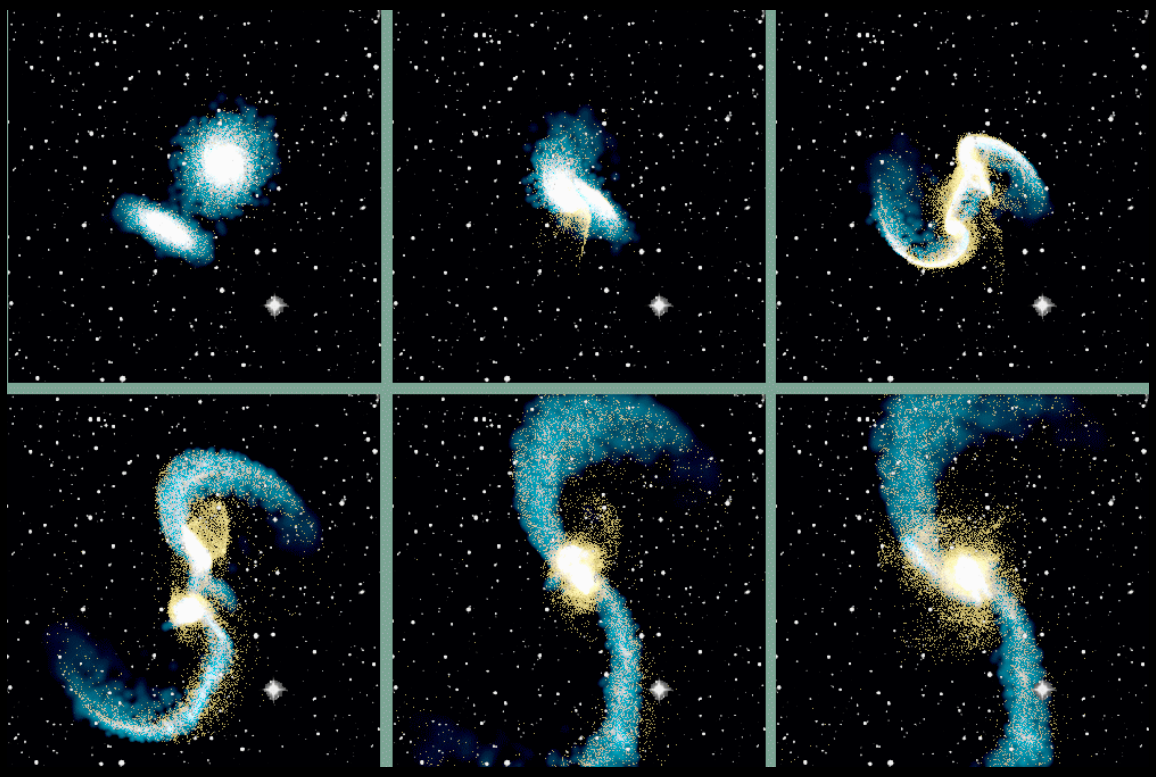
the beginning

galaxies interact and merge

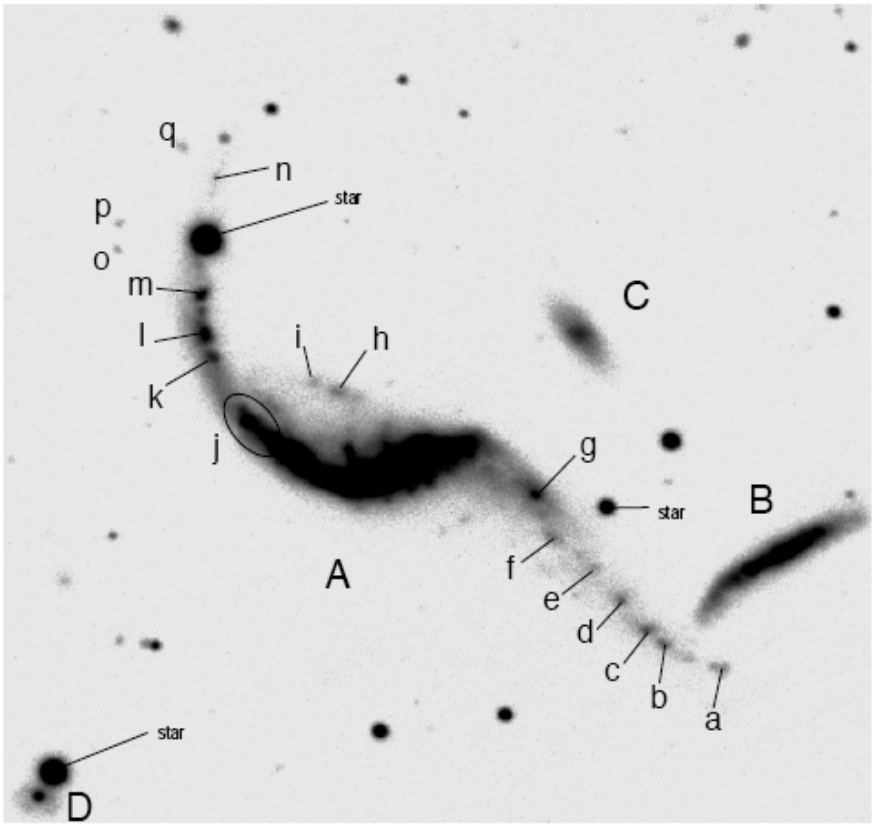
TDGs = tidal dwarf galaxies form

today

Tidal tails



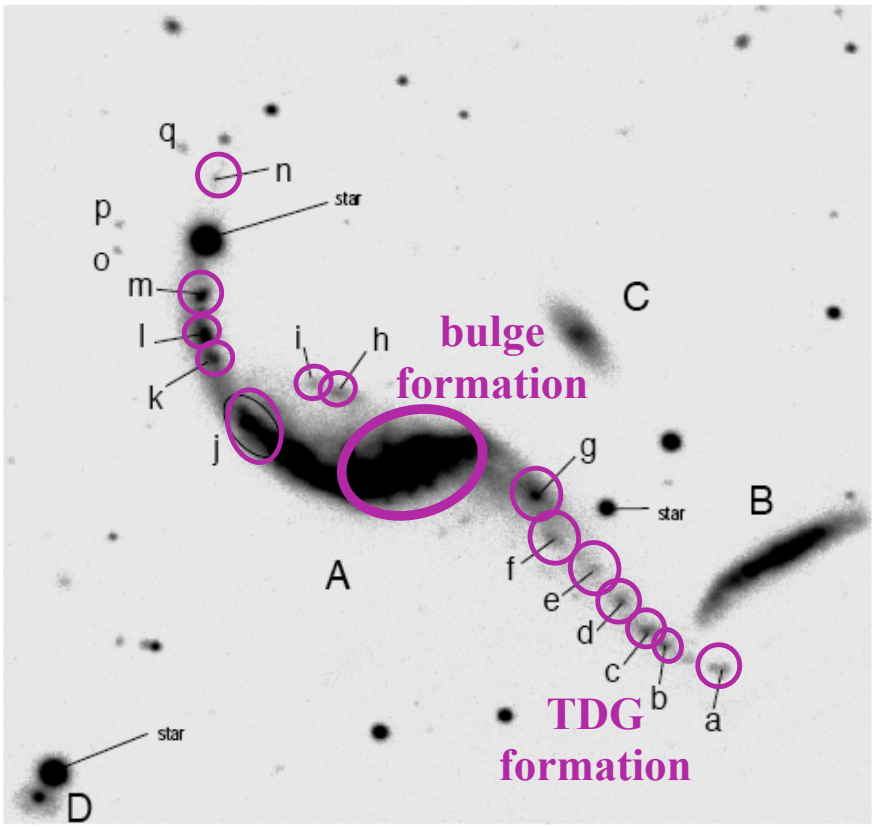
Miho & Maxwell, web



(Weilbacher et al. 2000)

$N_{\rm TDG} \approx 14$

Fig. 21. Identification chart of field 10 around AM 1353-272.

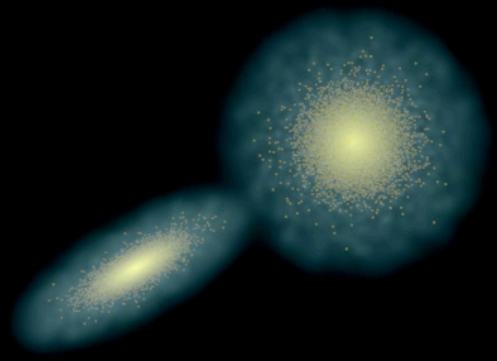


(Weilbacher et al. 2000)

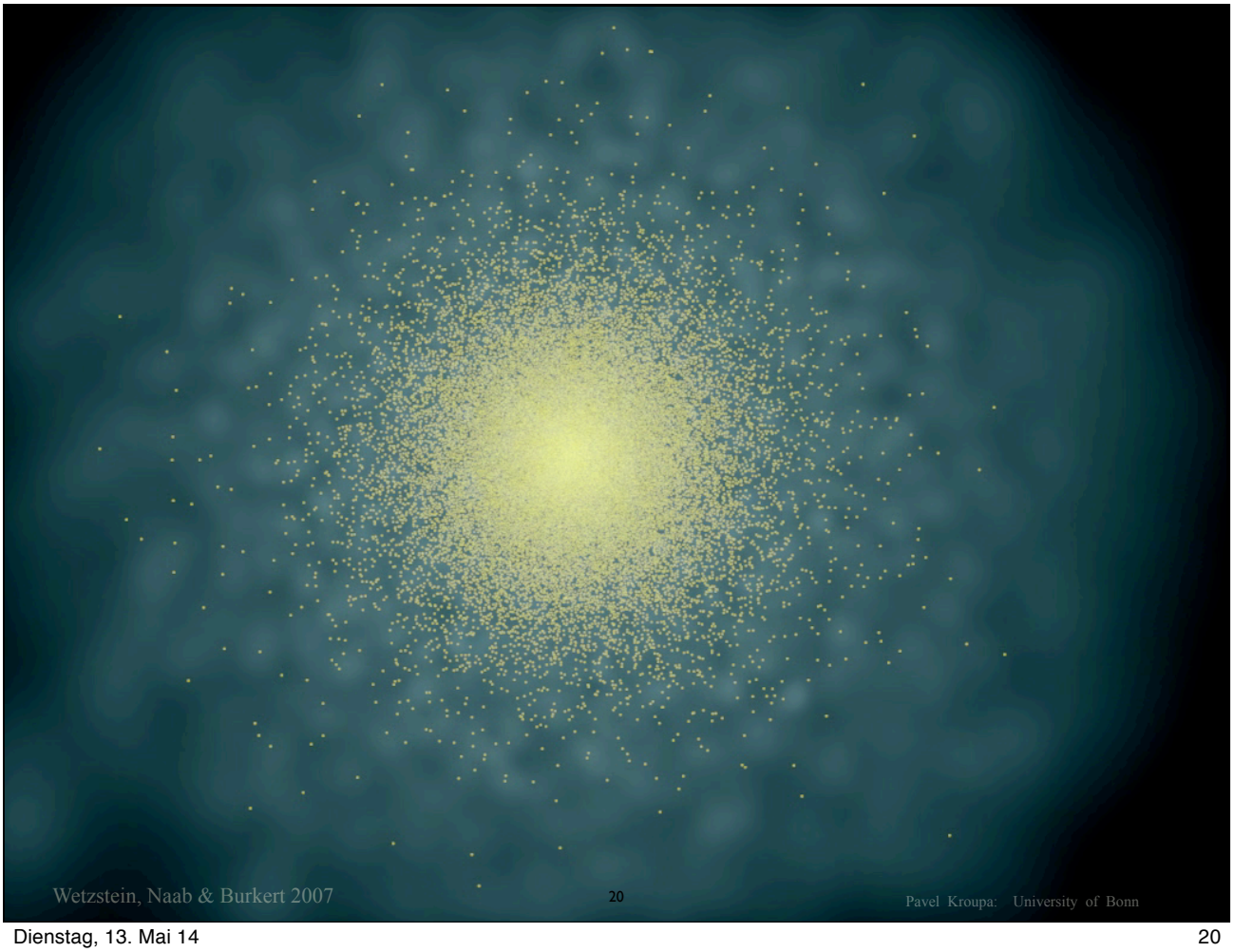
Phase-space correlated satellites form naturally in the same event as a *bulge* does.

Fig. 21. Identification chart of field 10 around AM 1353-272.

Relevance : The collision of two disks at high redshift



Wetzstein, Naab & Burkert 2007



Wetzstein, Naab & Burkert 2007

High-resolution self-consistent simulations of the chemo-dynamical evolution of young TDGs :

TDGs survive their feedback

TGDs do not dissolve

(Recchi et al. 2007 ; Ploeckinger et al. 2013)

High-resolution simulations of gas-poor TDGs orbiting within a dark matter host halo :

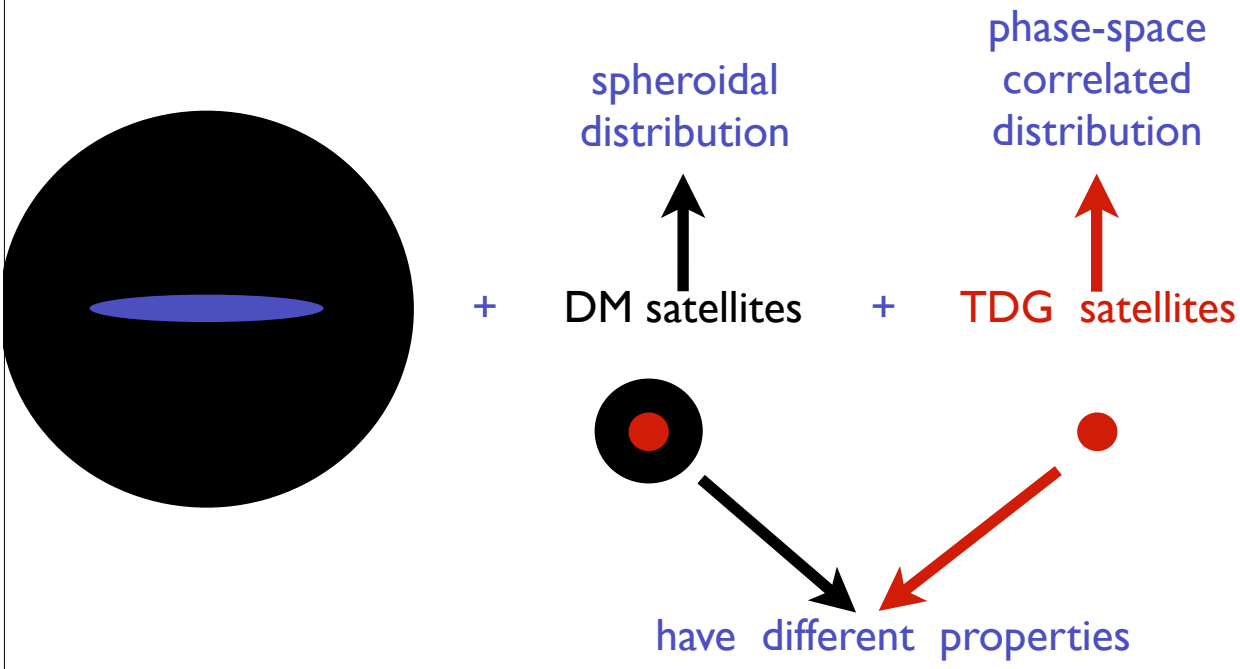
TDGs survive many Gyr
and may resemble
dark-matter dominated dSph/UFD satellite galaxies

(Kroupa 1997; Klessen & Kroupa 1998; Casas et al. 2012)

The Dual Dwarf-Galaxy Theorem

(Kroupa 2012)

Thus in the *Standard Model of Cosmology* (SMoC) a galaxy must look as follows:



The Dual Dwarf Galaxy Theorem must be true if the SMoC is true :

The Dual Dwarf Galaxy Theorem :

SMoC $\Rightarrow$ $\exists$ Type A dwarfs $\wedge$ Type B dwarfs

Kroupa 2012

with Dark Matter (DM) — spheroidal distribution

TDGs w/o DM — correlated in phase-space

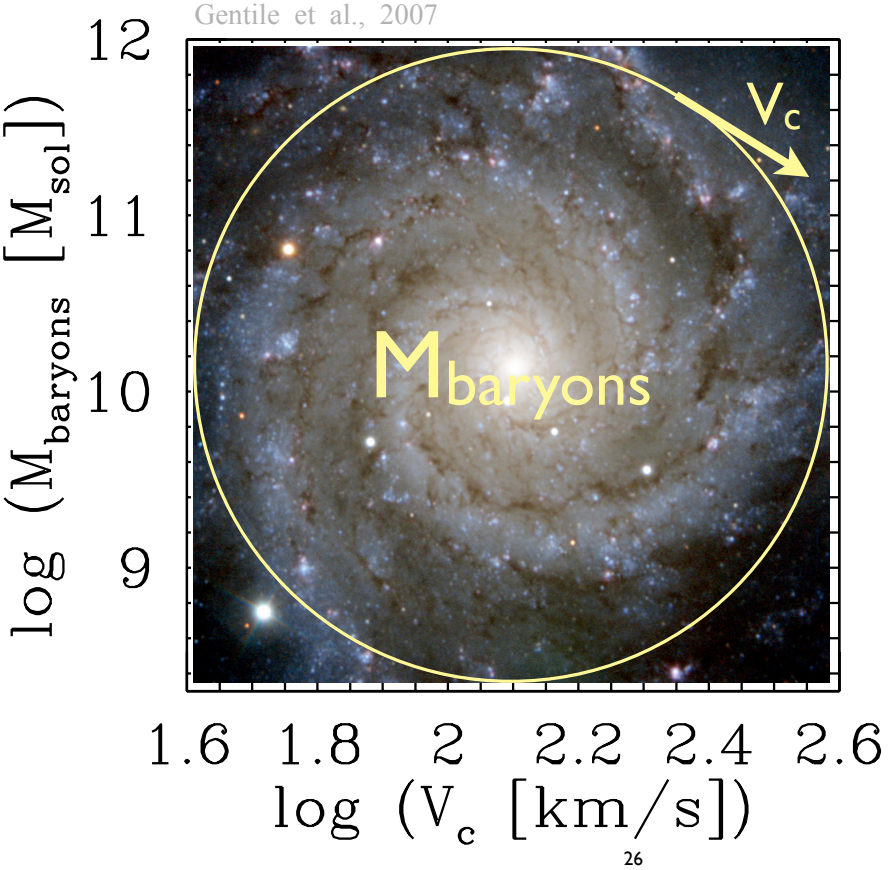
If only one type exists then the Dual Dwarf Galaxy Theorem is falsified.

Is there any evidence for the co-existence of two types of dwarf galaxy ?

Testing the dual dwarf-galaxy theorem

Rotationally-supported stellar systems

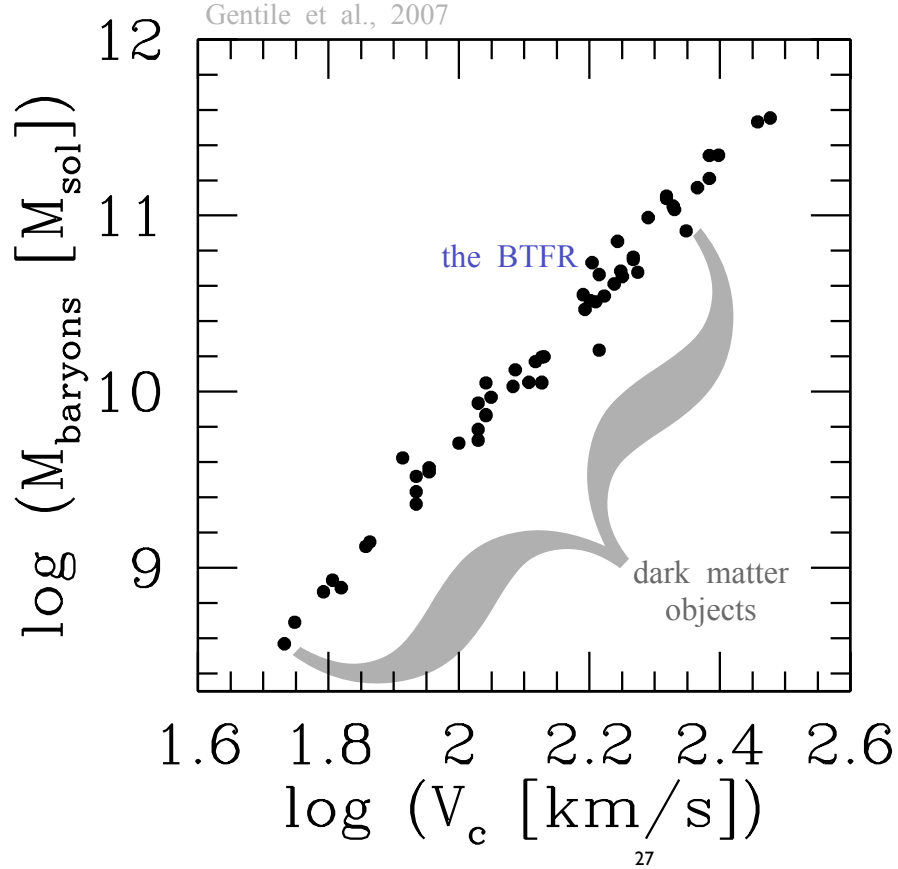
Gentile et al., 2007



The Baryonic Tully -Fisher Relation :

Rotationally-supported stellar systems

Gentile et al., 2007



The Baryonic Tully -Fisher Relation :

If the SMoC is true
then the
BTFR
must
be given
by the dark matter halo

and
tidal dwarf galaxies
cannot
lie on the same BTFR !

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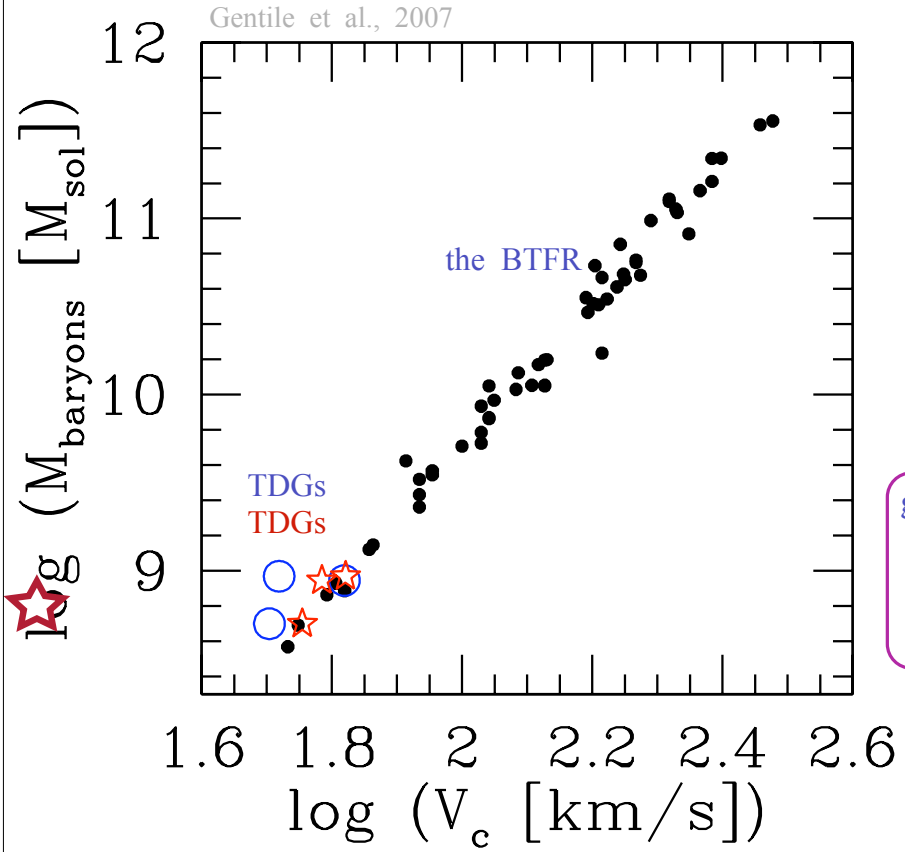
Rotationally-supported stellar systems

Gentile et al., 2007



The Baryonic Tully -Fisher Relation :

But TDGs do lie on the same BTFR

galaxies with dark matter
=
galaxies w/o dark matter
!

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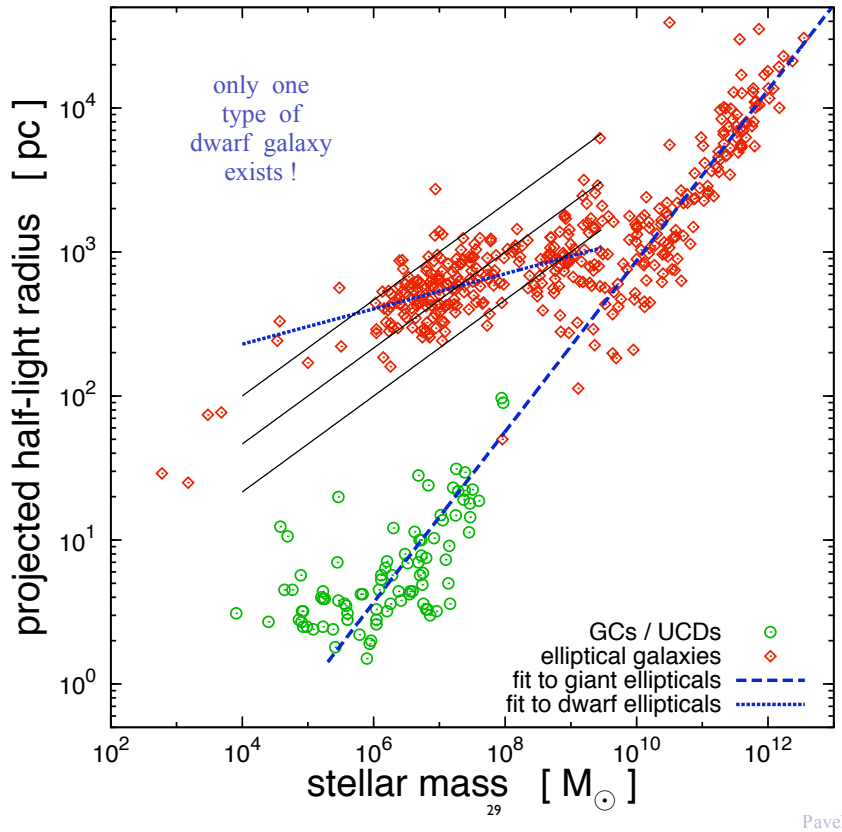
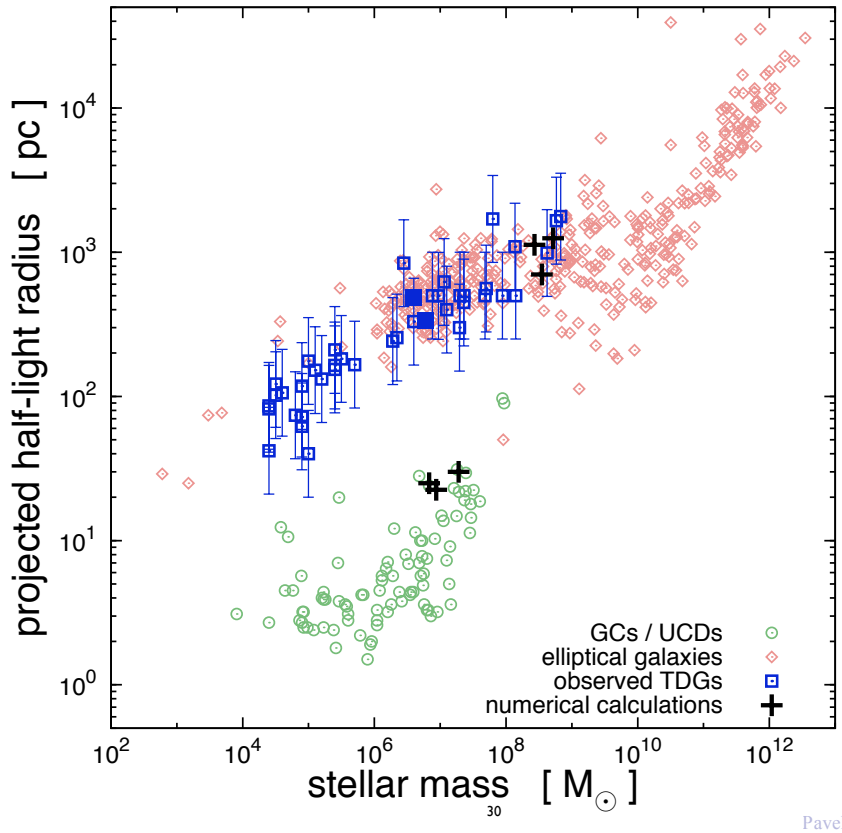
Pressure / random-motion supported stellar systems

Dabringhausen et al. 2012



Pressure / random-motion supported stellar systems

Dabringhausen et al. 2012



TDGs coincide with dE / dSph satellites

galaxies with dark matter = galaxies w/o dark matter !

Thus:

Kroupa 2012;
Dabringhausen & Kroupa 2013

The Dual Dwarf Galaxy Theorem :

SMoC $\Rightarrow$ $\exists$ Type A dwarfs $\wedge$ Type B dwarfs

$\Rightarrow$ only one type of dwarf galaxy is observed.

$\Rightarrow$ Dual Dwarf Galaxy Theorem is falsified.

Remember now elementary logics:

if A then B

$\Leftrightarrow$

if not B then not A

$\Updownarrow$

Type A dwarf = Type B dwarf $\Rightarrow$ ~~SMoC~~

has been shown

END of Proof

Consistency Checks

Remember :

The Dual Dwarf Galaxy Theorem must be true if the SMoC is true **:**

Kroupa 2012; Dabringhausen & Kroupa 2013

The Dual Dwarf Galaxy Theorem :

SMoC $\Rightarrow$ $\exists$ Type A dwarfs $\wedge$ Type B dwarfs

with DM — TDGs w/o DM

spheroidal distribution

correlated in phase-space

consistency check next . . .

Concistency Check I

If
the Milky Way satellites are
TDGs without dark matter
then
they ought to be in a
phase-space correlated distribution.

Vast Polar Structure around the Milky Way

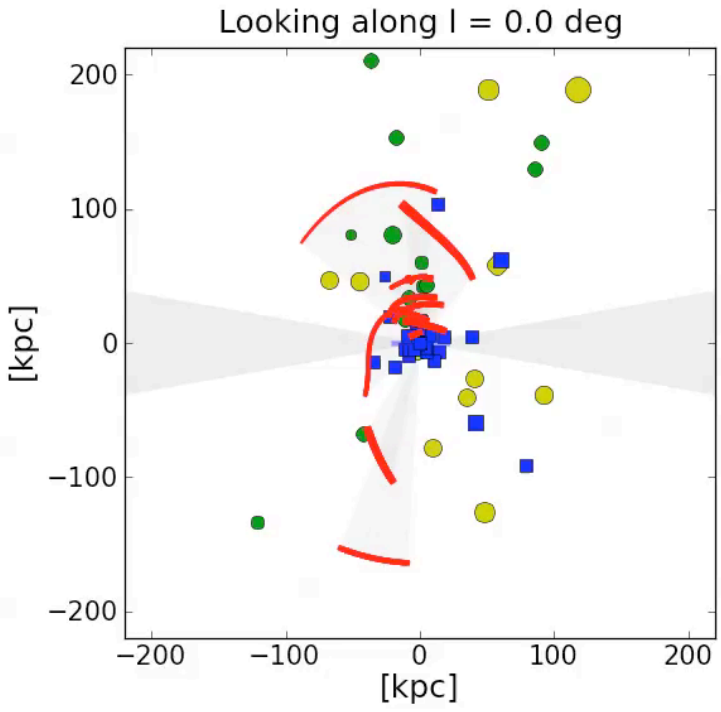
Pawlowski et al. 2012

YH globular clusters

dSph satellites

UFD satellites

streams



See also Pawlowski's ***YouTube video*** "The Vast Polar Structure"

Vast Polar Structure around the Milky Way

Pawlowski et al. 2012

YH globular clusters

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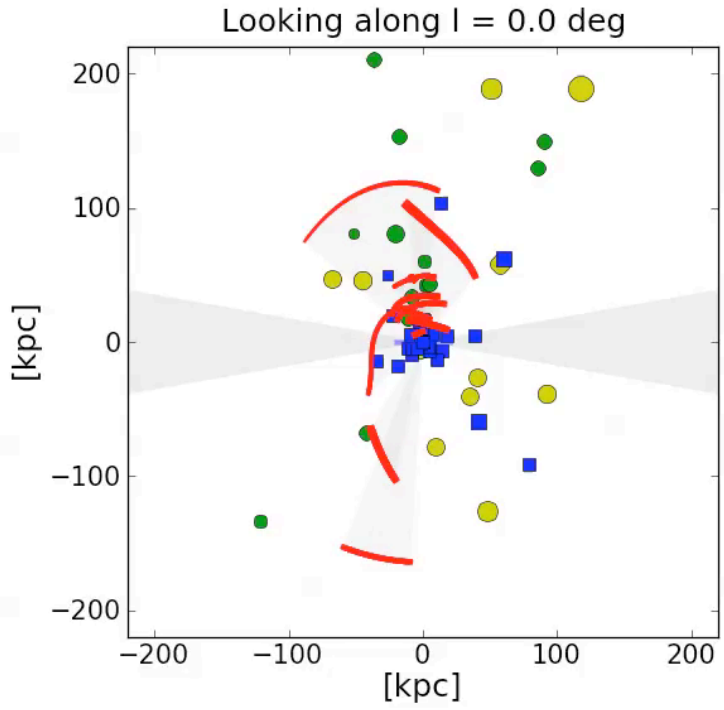
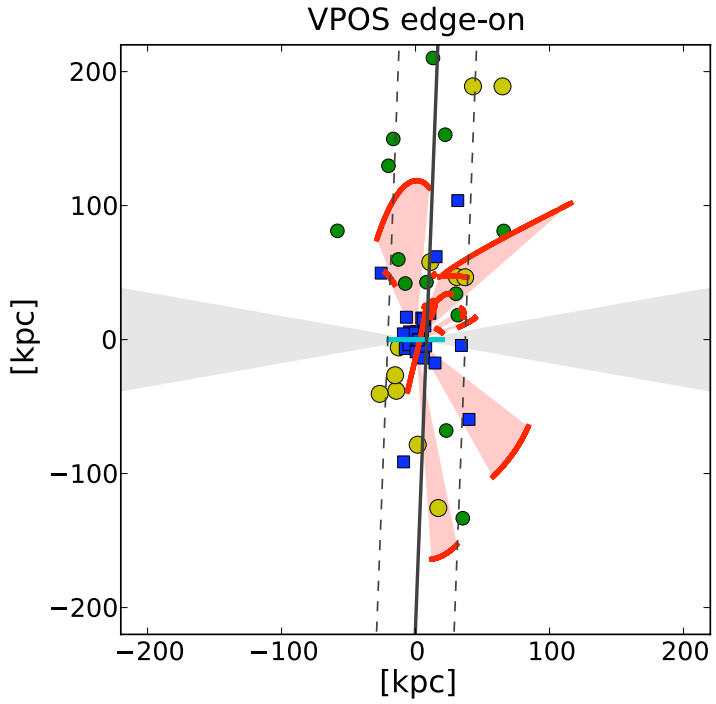


See also Pawlowski's *YouTube video* "The Vast Polar Structure"

Vast Polar Structure around the MW

Pawlowski et al. 2012



http://sf2a.eu/semaine-sf2a/2013/proceedings/2013sf2a.conf..0363L.pdf

THE SEARCH FOR NEW MILKY WAY DWARF GALAXIES IN THE PAN-STARRS 1 PANOPTIC SURVEY

B. P. M. Laevens[1,2], N. F. Martin[1,2], H.-W. Rix[2] and Pan-STARRS 1 collaboration

Abstract. We present the latest results of the on-going search for faint dwarf galaxies in the surroundings of the Milky Way within Pan-STARRS 1 data. Covering three quarters of the sky the on-going Pan-STARRS 1 survey is a photometric survey in optical and near-infrared bands. Applying a convolution method to identify overdensities, followed by a preliminary analysis of the object detection significance led to no obvious dwarf galaxy candidates in regions of the sky not previously surveyed by the Sloan Digital Sky Survey. This result questions the isotropy of the Milky Way dwarf galaxy satellite system.

Concistency Check I

If
the Milky Way satellites are
TDGs without dark matter
then
they ought to be in a
phase-space correlated distribution.

YES they are !

If the MW satellites are DM dominated sub-halos, then

A) they have to have fallen-in recently (z<1) in order to be arranged in the DoS/VPOS
Deason et al. (2011)

AND

B) they have to have fallen in a long time ago (z=3-10) in order for them to have lost their gas
Nichols & Bland-Hawthorn (2011)

A and B are mutually exclusive.

==> the satellites cannot be dark-matter sub-halos .

An important clue follows from the ***Andromeda satellite system*:**

The *vast thin disk (VTD)* of satellites can only be understood if the satellites in the VTD are *TDGs* (Hammer et al. 2013; Yang et al. 2014).

But each has an identical *very large dark-matter content* as those satellites which are not in the VTD.

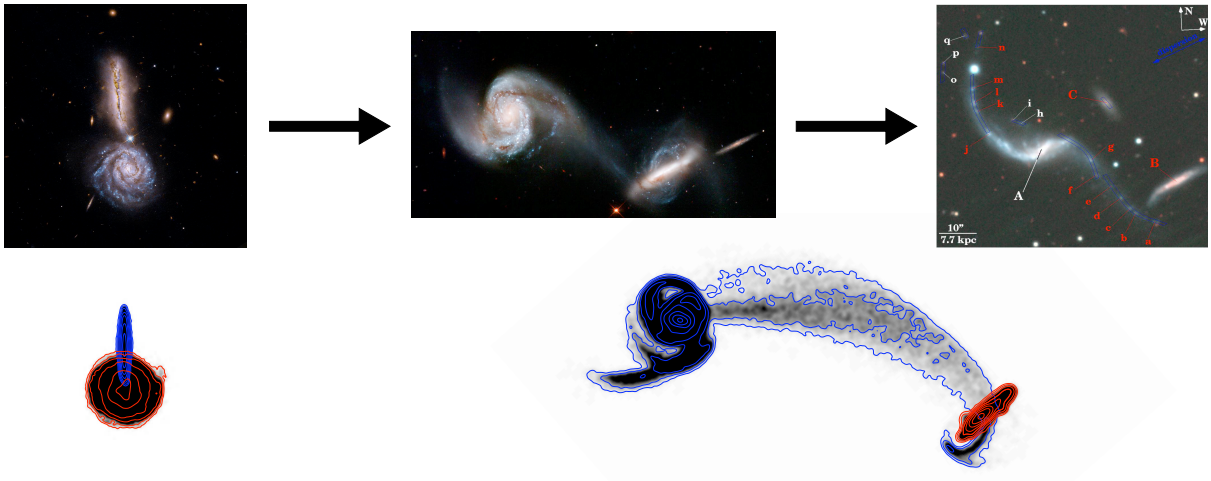
TDGs + DM => logical inconsistency

Only solution: *gravity is not Newtonian* (or DM has extremely complicated dynamics)

Origin of the Vast Polar Structure ?

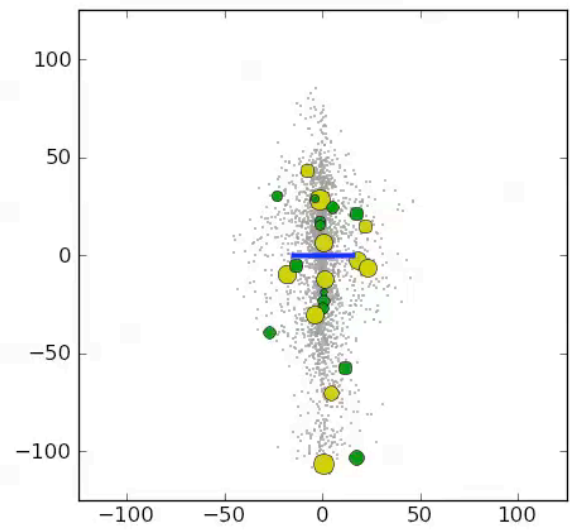
Phase-space-correlated tidal debris

Pawlowski et al. 2012

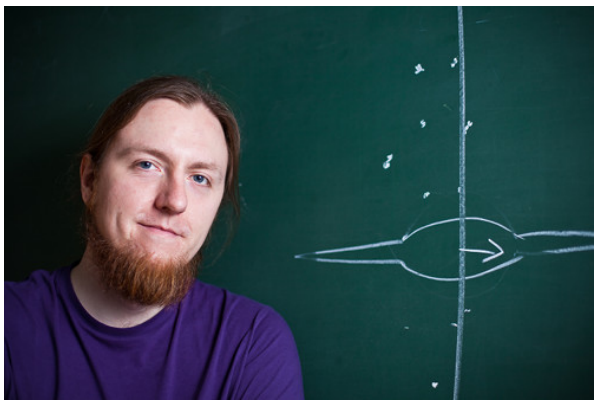


Fly-by encounter: e.g. Milky Way and Andromeda ? about 10-11 Gyr ago

Pawlowski et al. 2011



See also Fouquet, Hammer et al. (2012) for another elegant explanation.



Marcel Pawlowski (Bonn) / structure of Local Group

Joerg Dabringhausen (Bonn) / properties of TDGs

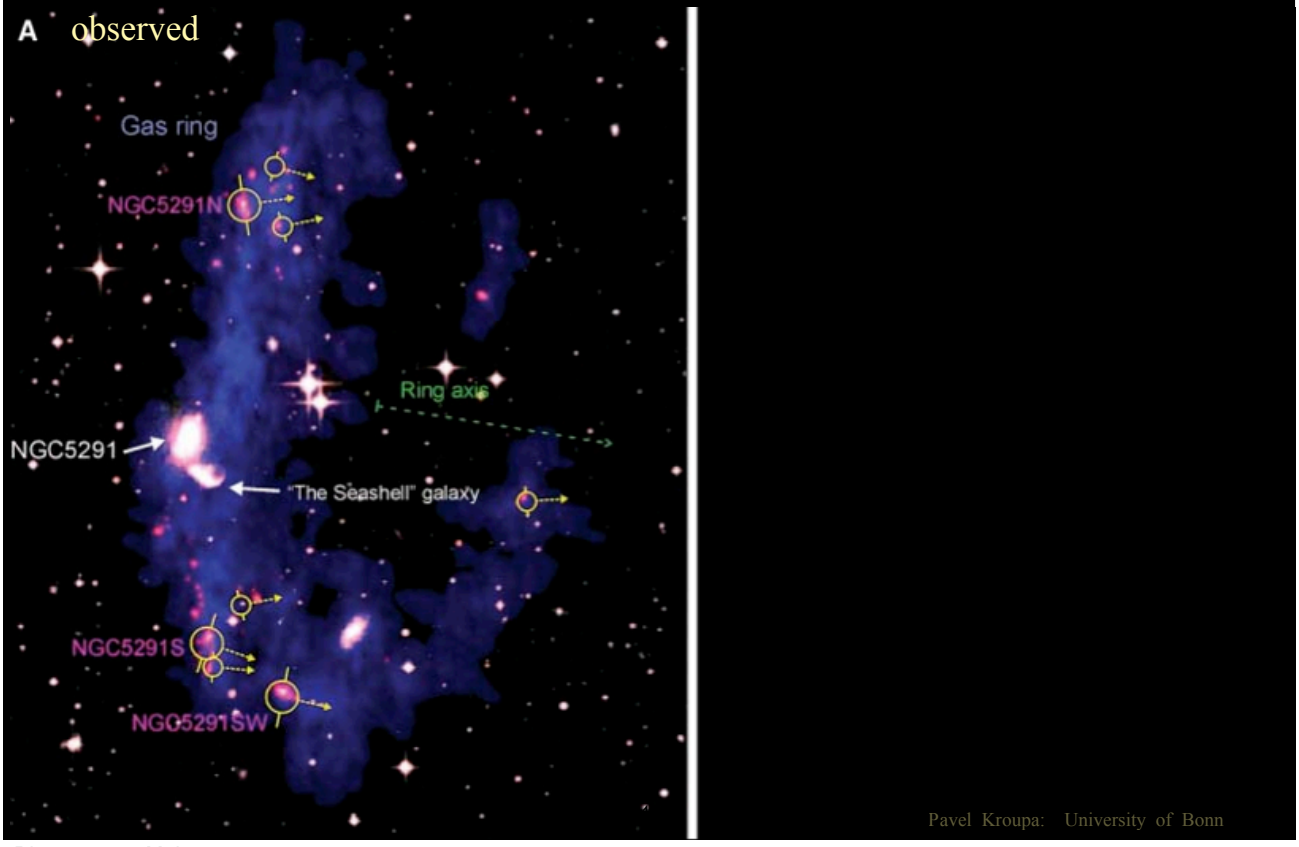
Sylvia Ploeckinger (Vienna) / evolution of TDGs

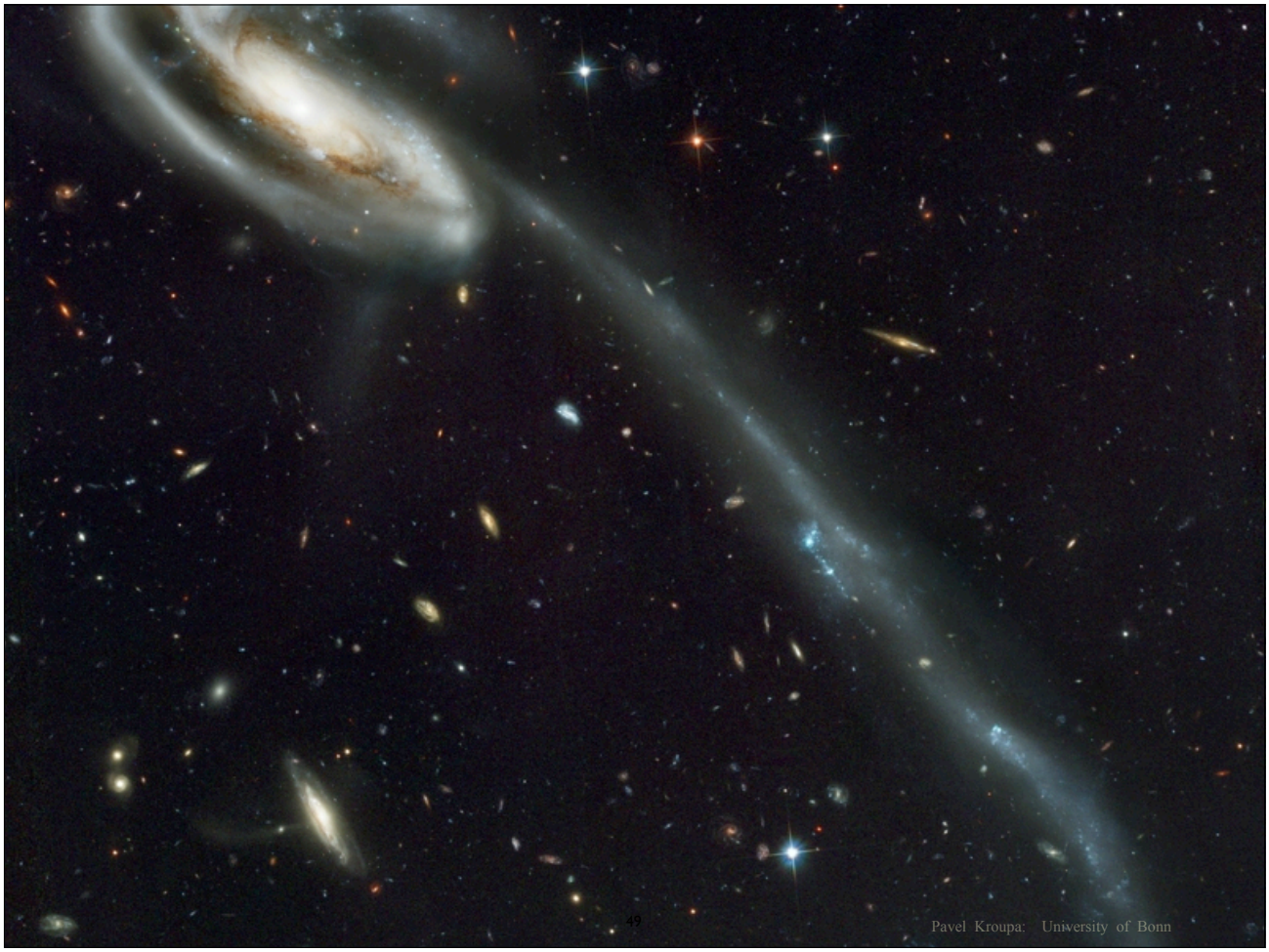
Concistency Check II

Other, extra-galactic,
phase-space correlated distributions
of satellite systems.

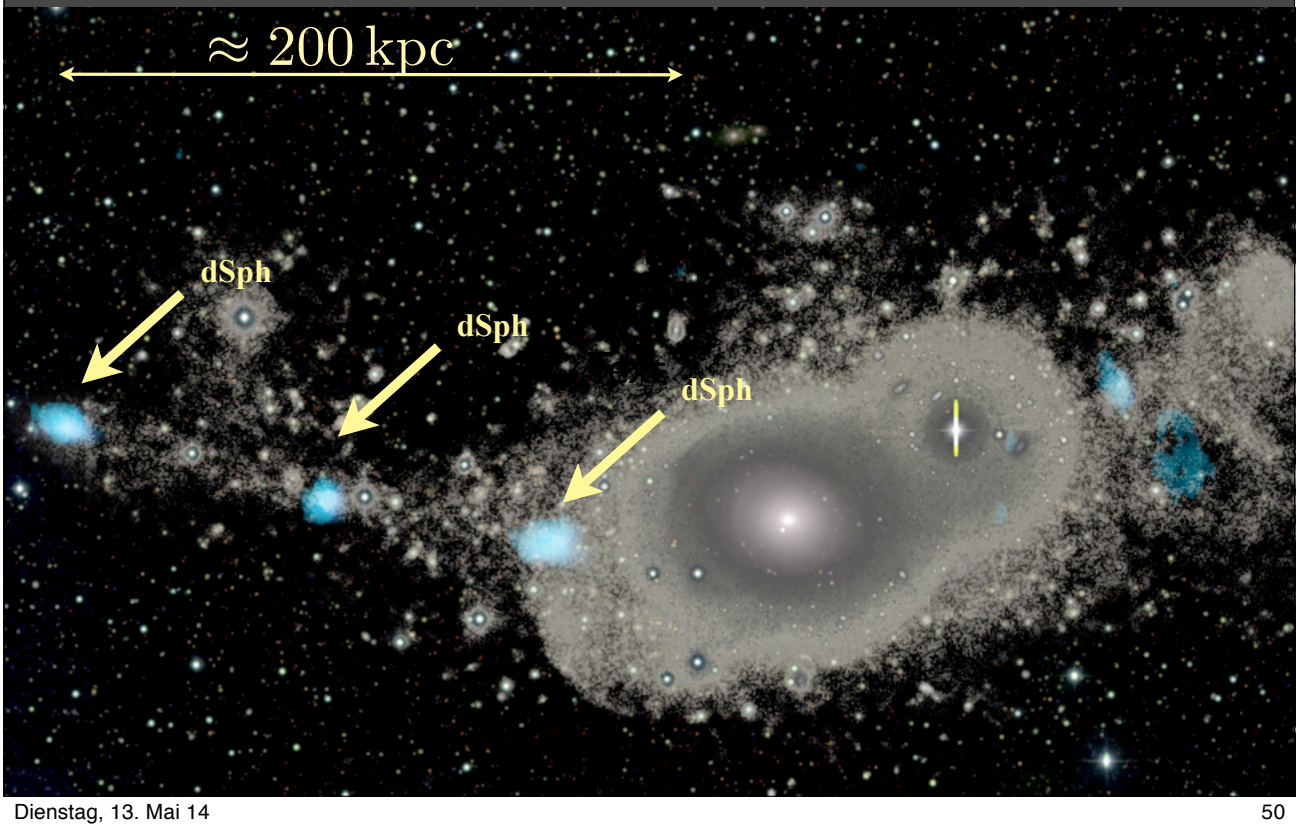
Is the Milky Way galaxy unique or an extreme outlier **?**

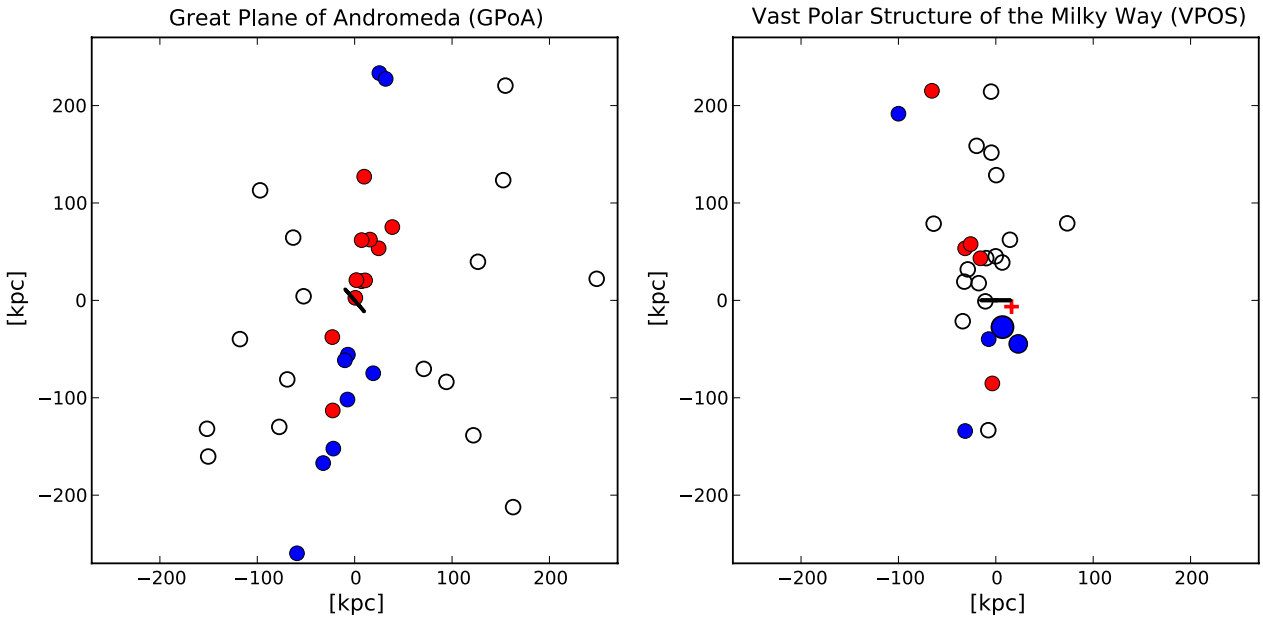
Bournaud et al. (2007, Science)





NGC 5557 (post-merger 2-3 Gyr)





Ibata et al. 2013, 2014

Pawlowski & Kroupa 2013

Pawlowski, Kroupa & Jerjen (2013 MNRAS)

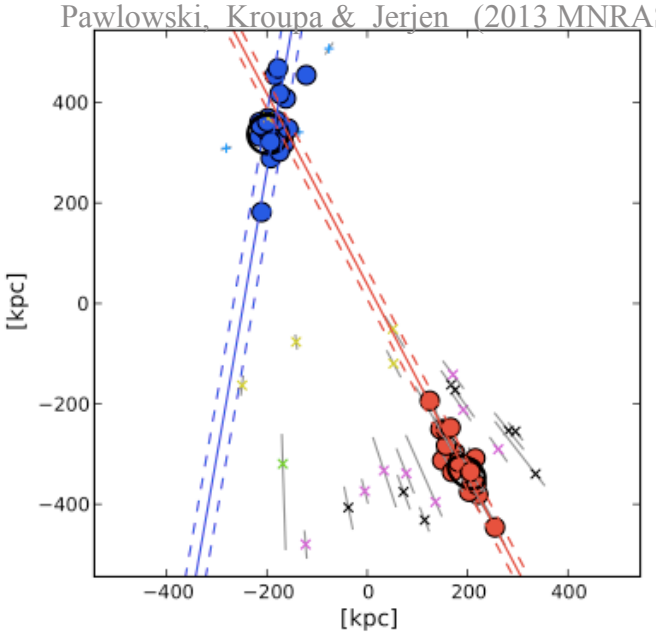


Figure 16. Edge-on view of the satellite galaxy planes around the MW and M31, similar to Fig. 9 for the LG planes. As before, galaxies which are

Pawlowski, Kroupa & Jerjen (2013 MNRAS)

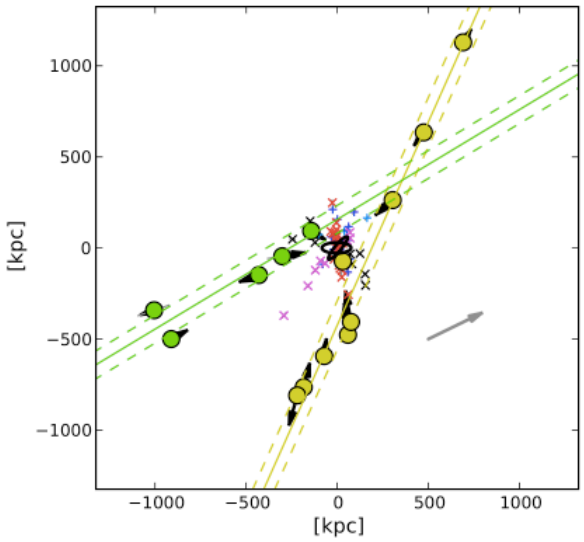


Figure 9. Edge-on view of both LG planes. The orientation of the MW and M31 are indicted as black ellipses in the centre. Members of the LGP1 are plotted as yellow points, those of LGP2 as green points. MW galaxies are plotted as plus signs (+), all other galaxies as crosses (×), the colours code their plane membership as in Fig. 6. The best-fitting planes are plotted as

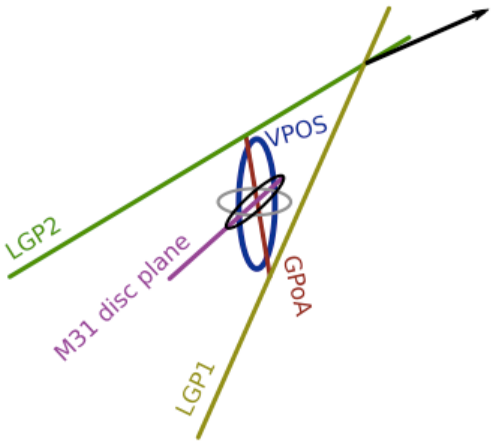
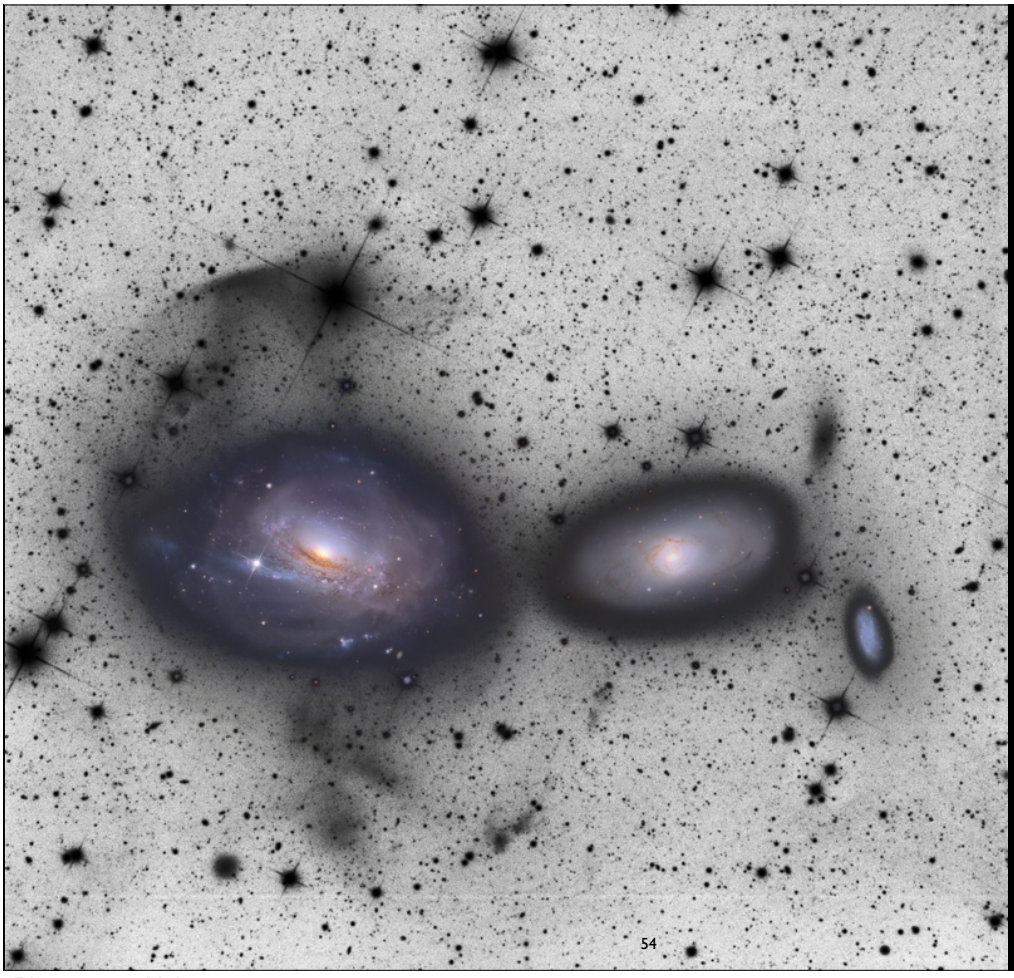
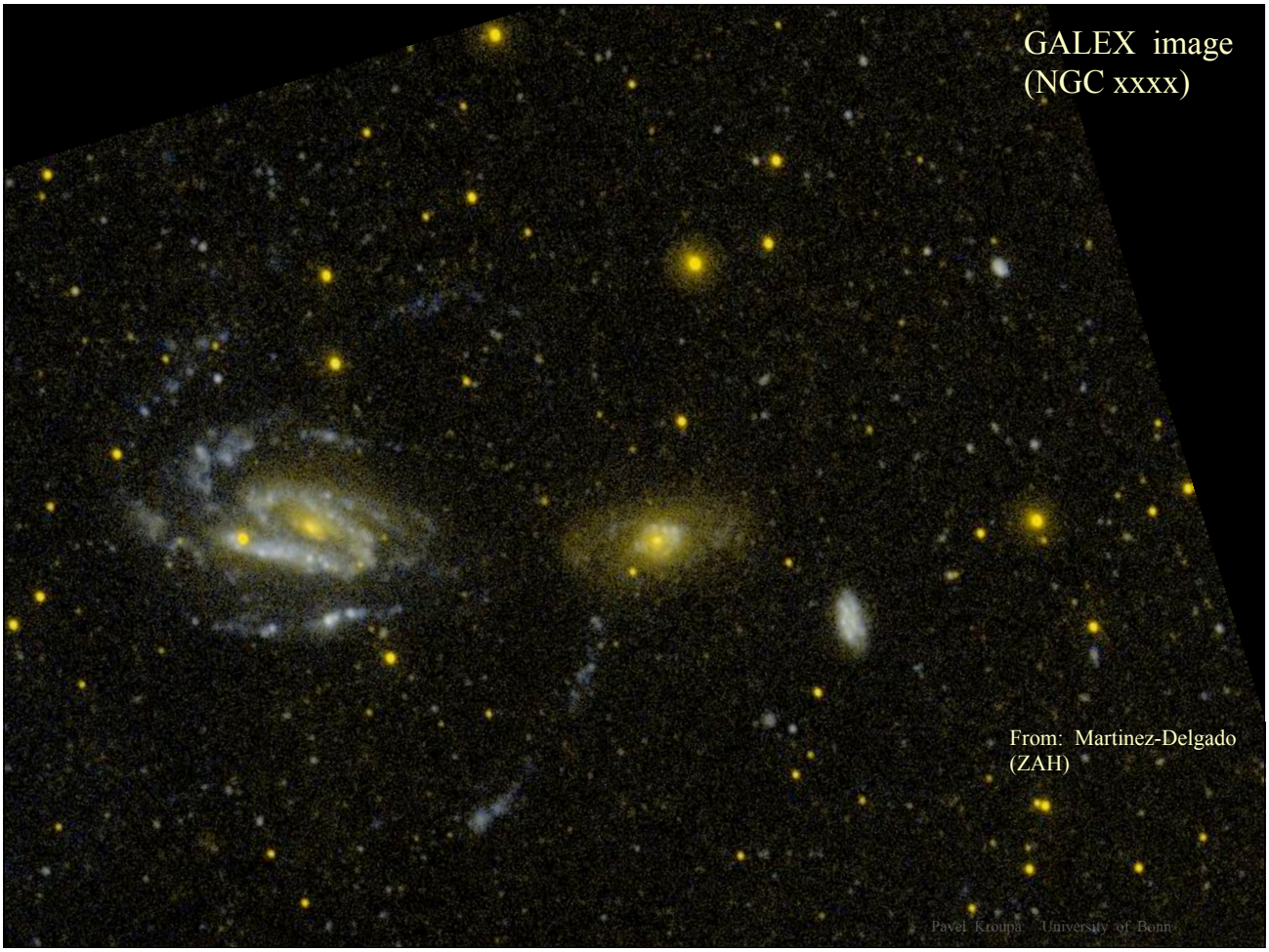


Figure 18. Cartoon of the LG structure (compare to Fig. 9). The positions and orientations of the galactic discs of the MW (grey) and of M31 (black) are indicated by the ellipses in the centre. Looking along the MW–M31 line, most planes in the LG are seen approximately edge-on, the only exception is the VPOS plane (blue), which is inclined relative to this view. The arrow indicates the direction of motion of the LG relative to the CMB.



The formation of faint dwarf galaxies in the interaction between two spirals (NGC xxxx)

Credit: Martinez-Delgado (ZAH) and Adam Block (MtLemmon Obs)



Concistency Check II

Other, extra-galactic,
phase-space correlated distributions
of satellite systems.

Is the Milky Way galaxy unique or an extreme outlier ?

NO, it is not !

Chiboucas et al. (2013, AJ) write

"*In review, in the few instances around nearby major galaxies where we have information, in every case there is evidence that gas poor companions lie in flattened distributions*"

Remember :

Kroupa 2012

The Dual Dwarf Galaxy Theorem must be true if the SMoC is true **:**

The Dual Dwarf Galaxy Theorem :

SMoC $\Rightarrow$ $\exists$ Type A dwarfs $\wedge$ Type B dwarfs

with DM — TDGs w/o DM

spheroidal distribution — correlated in phase-space

consistency check next . . .

Thus:

Kroupa 2012

The Dual Dwarf Galaxy Theorem :

SMoC $\Rightarrow$ $\exists$ Type A dwarfs $\wedge$ Type B dwarfs

$\Rightarrow$ only one type of dwarf galaxy is observed.

$\Rightarrow$ Dual Dwarf Galaxy Theorem is falsified.

$\Updownarrow$

Type A dwarf = Type B dwarf $\Rightarrow$ ~~SMoC~~

has been shown

Thus:

Kroupa 2012

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$\Updownarrow$

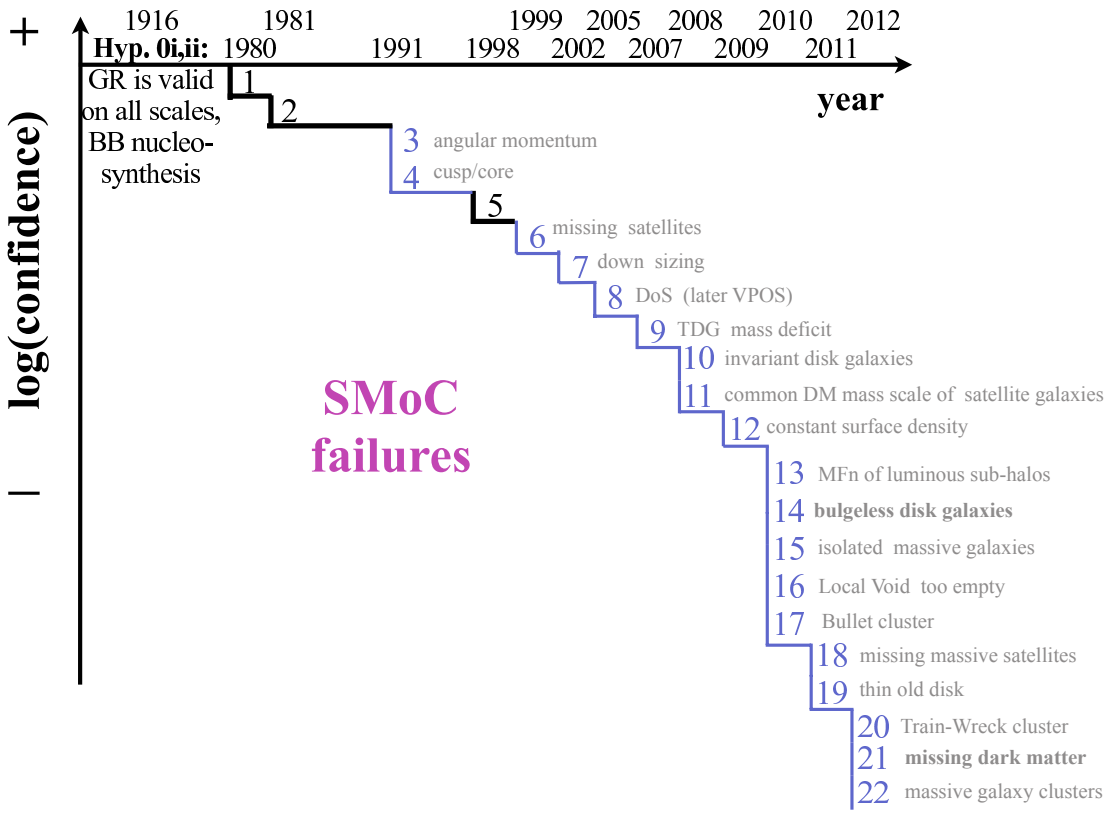
Type A dwarf = Type B dwarf $\Rightarrow$ ~~SMoC~~

has been shown

If this falsification is true,
then the
standard model of cosmology
must show other and general
discrepancies
with data . . .

The Theory Confidence Graph

Kroupa 2012



Kroupa 2012

Cold or warm dark matter particles therefore cannot exist.

(**Remember:** Cold or warm dark matter is postulated as a result of adopting the Einstein's field equation on galactic and cosmological scales)

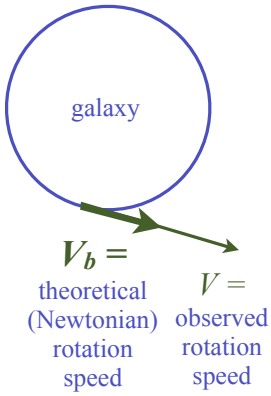
Which impact does this have for fundamental physics ?

Do the data on galaxy-scales contain clues ?

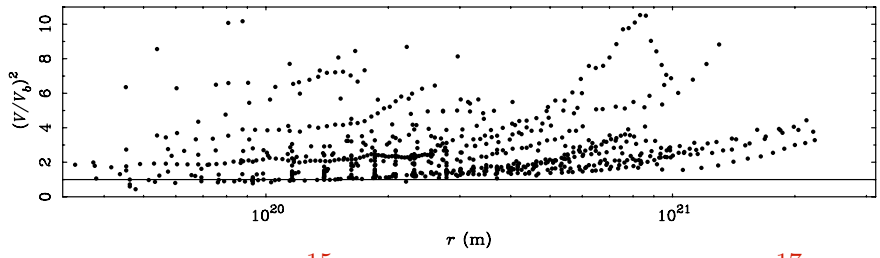
Mass-Discrepancy correlation with acceleration

The Sanders-McGaugh correlation

Sanders 1990; McGaugh 2004
Famaey & McGaugh 2012
Kroupa 2012

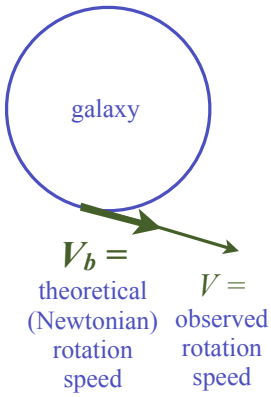


Mass-Discrepancy correlation with acceleration

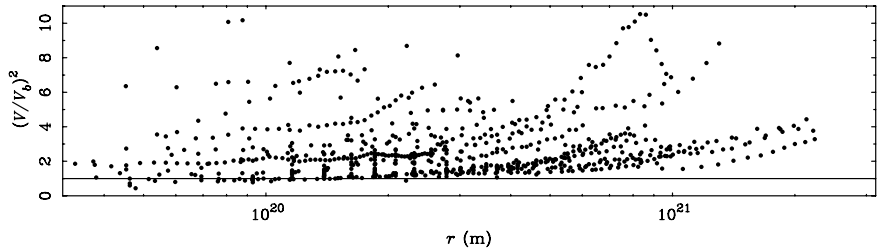


Sanders 1990; McGaugh 2004
Famaey & McGaugh 2012
Kroupa 2012

$1\ \mathrm{pc} = 31 \times 10^{15}\ \mathrm{m}$ $\quad$ $1\ \mathrm{m} = 3.2 \times 10^{-17}\ \mathrm{pc}$

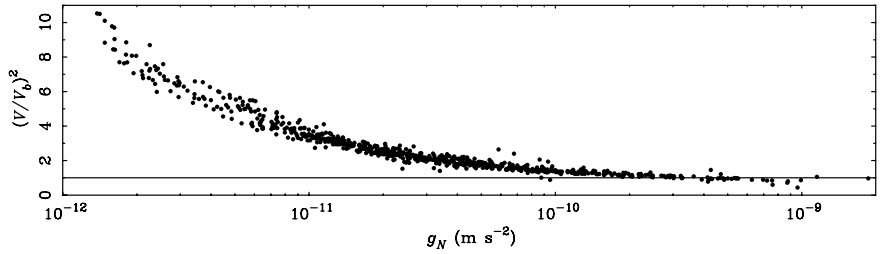


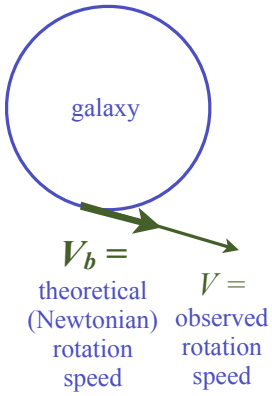
Mass-Discrepancy correlation with acceleration



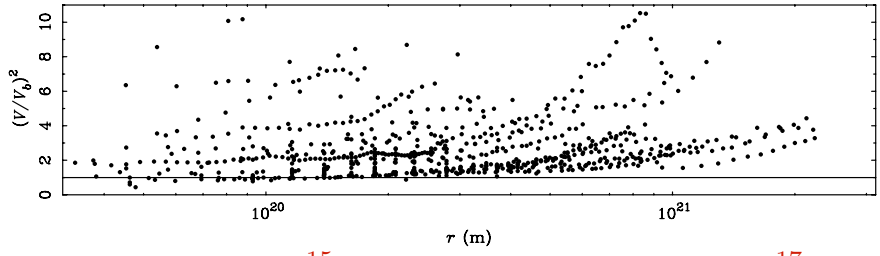
Sanders 1990; McGaugh 2004
Famaey & McGaugh 2012
Kroupa 2012

$1\ \mathrm{pc} = 31 \times 10^{15}\ \mathrm{m}$ $\quad$ $1\ \mathrm{m} = 3.2 \times 10^{-17}\ \mathrm{pc}$



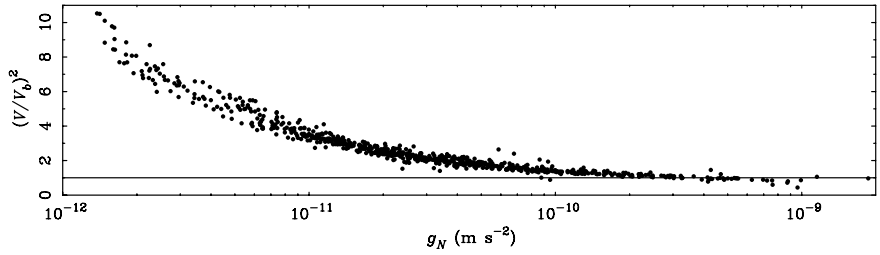


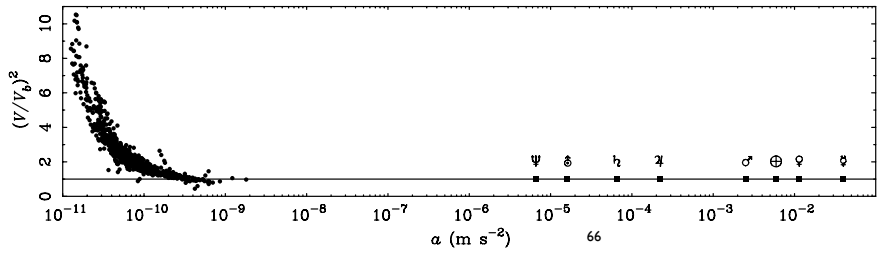
Mass-Discrepancy correlation with acceleration



Sanders 1990; McGaugh 2004
Famaey & McGaugh 2012
Kroupa 2012

$1\ \mathrm{pc} = 31 \times 10^{15}\ \mathrm{m}$ $\quad$ $1\ \mathrm{m} = 3.2 \times 10^{-17}\ \mathrm{pc}$





Correlation can't be explained by Dark Matter : DM particle physics is independent of the local acceleration in the SMoC.

Mass-Discrepancy correlation with acceleration

McGaugh 2014

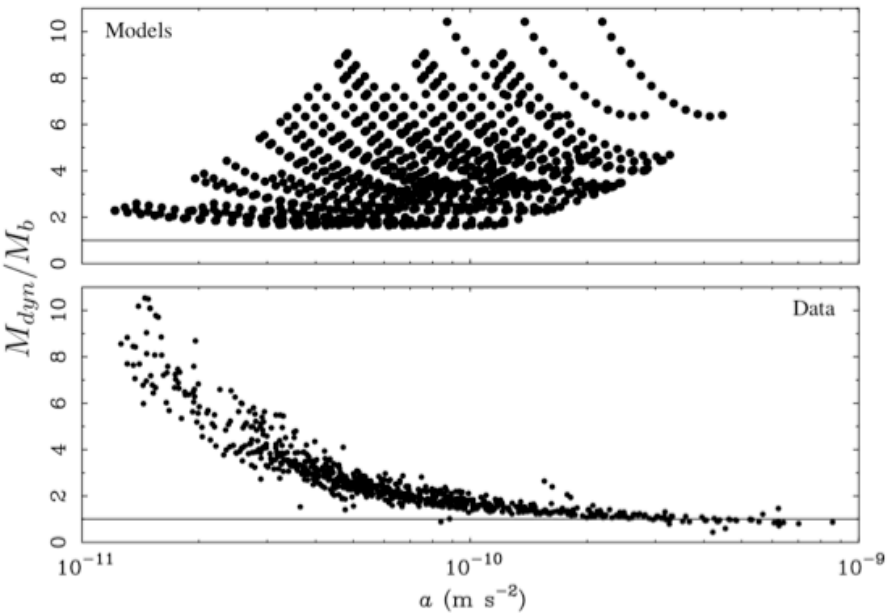


Fig. 3. The mass discrepancy–acceleration relation. The ratio of dynamical to baryonic mass is shown at each point along rotation curves as a function of the centripetal acceleration at that point. The top panel shows model galaxies in ΛCDM (see text). The bottom panel shows data for real galaxies (42). Individual galaxies, of which there are 74 here, do not distinguish themselves in this diagram, though model galaxies clearly do. The organization of the data suggest the action of a single effective force law in disk galaxies. This phenomenon does not emerge naturally from ΛCDM models.

Correlation can't be explained by Dark Matter : DM particle physics is independent of the local acceleration in the SMoC.

$1\ \mathrm{pc} = 31 \times 10^{15}\ \mathrm{m}$ $\qquad$ $1\ \mathrm{m} = 3.2 \times 10^{-17}\ \mathrm{pc}$

space-time

Scale-Invariant

Dynamics

(SID)

Consider *space-time scale invariance* :

(**Milgrom 2009**; Kroupa, Pawlowski & Milgrom 2012)

If $(t, x, y, z) \rightarrow \lambda(t, x, y, z)$

then, the Newtonian gravitational acceleration, $g_N \propto GM/r^2$,
scales as $g_N \rightarrow \lambda^{-2} g_N$

while the kinematical acceleration, g , scales as $g \rightarrow \lambda^{-1} g$ $\left[\frac{d\dot{x}}{dt}\right]$

For gravitational and kinematical acceleration to also be scale invariant we thus need g to scale as $g_N^{1/2}$

i.e. $g \propto \left(a_o g_N\right)^{1/2}$ $\qquad g^2 = a_o g_N$ or $a^2 = a_o g_N$

i.e. $\frac{a}{a_o} a = g_N$

space-time scale invariance (from above) :

i.e. $\frac{a}{a_o} a = g_N$, thus $a = \frac{\sqrt{GM}}{r}\sqrt{a_0}$

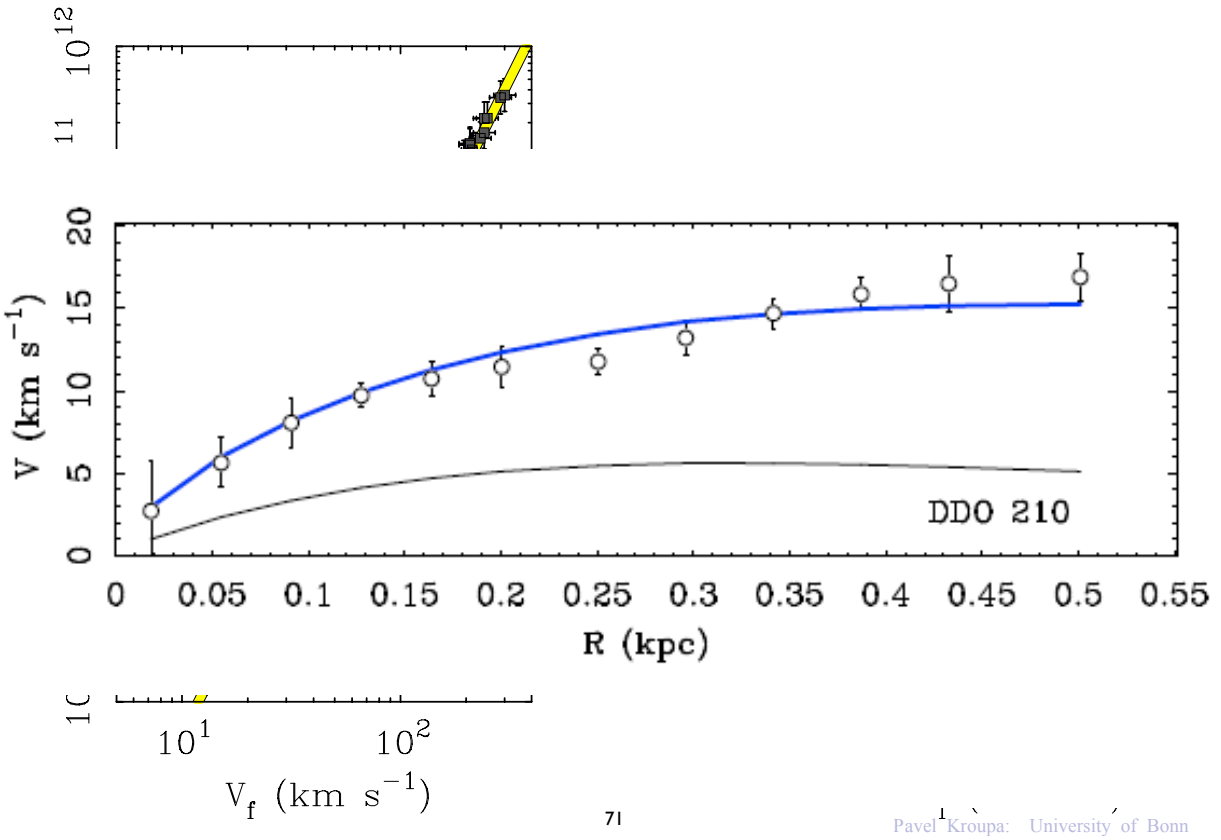
centrifugal acceleration = centripetal acceleration

$\Rightarrow$ $a = \frac{V^2}{r} = \frac{\sqrt{GMa_0}}{r}$ $\qquad (V \equiv V_c)$

$V = (GMa_0)^{\frac{1}{4}}$ the ***Tully-Fisher relation !***
and ***flat rotation curves !***

The observational Baryonic Tully -Fisher Relation

Famaey & McGaugh 2012



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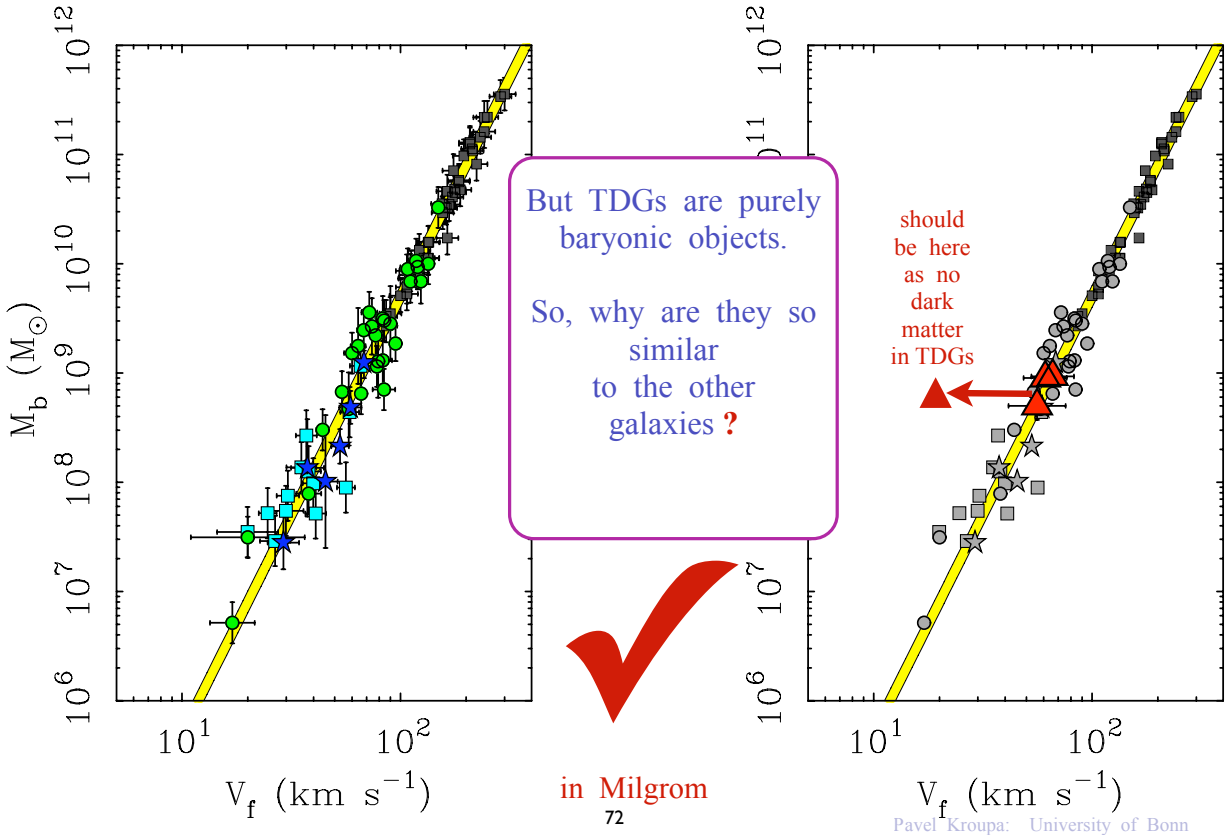
The observational Baryonic Tully -Fisher Relation

Famaey & McGaugh 2012



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Consider *space-time scale invariance* :

(Milgrom 2009; Kroupa, Pawlowski & Milgrom 2012)

If $(t, x, y, z) \rightarrow \lambda(t, x, y, z)$

$$\Rightarrow \quad g^2 = a_o g_N \quad \text{or} \quad a^2 = a_o g_N$$

$$\text{i.e.} \quad \frac{a}{a_o} a = g_N$$

Since $V^2 = (G a_0 M)^{\frac{1}{2}}$

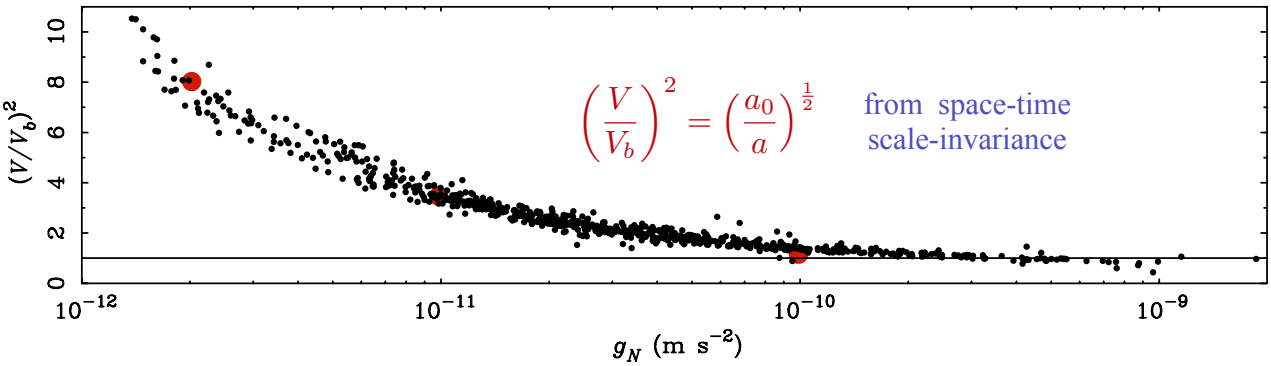
$$V_b^2 = \frac{GM}{r}$$

$$\Rightarrow \quad \left(\frac{V}{V_b}\right)^2 = \frac{(G a_0 M)^{\frac{1}{2}}}{r \frac{GM}{r^2}} = \frac{(G a_0 M)^{\frac{1}{2}}}{ra} = \left(\frac{a_0}{a}\right)^{\frac{1}{2}}$$

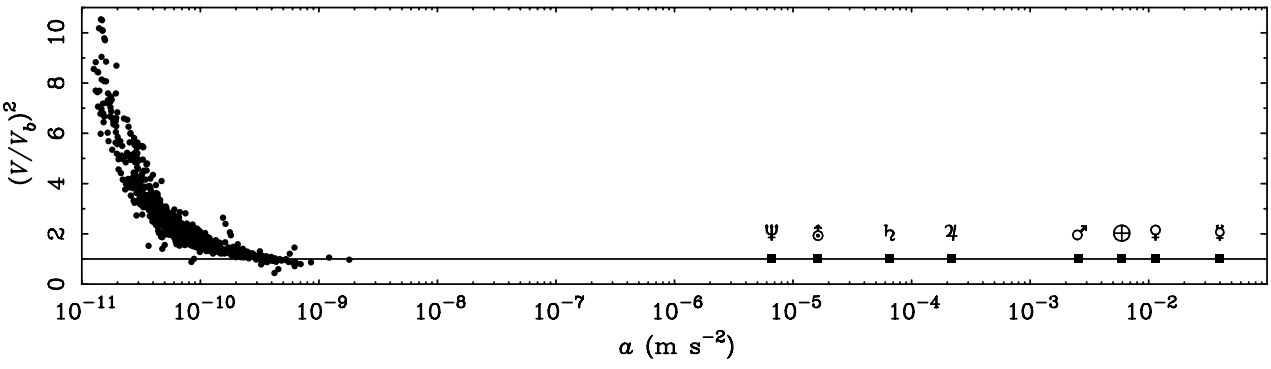
$$\text{i.e.} \quad \left(\frac{V}{V_b}\right)^2 = \left(\frac{a_0}{a}\right)^{\frac{1}{2}}$$

Mass-Discrepancy correlation with acceleration

The Sanders-McGaugh correlation explained



$\left(\frac{V}{V_b}\right)^2 = \left(\frac{a_0}{a}\right)^{\frac{1}{2}}$ from space-time scale-invariance



Conclusions

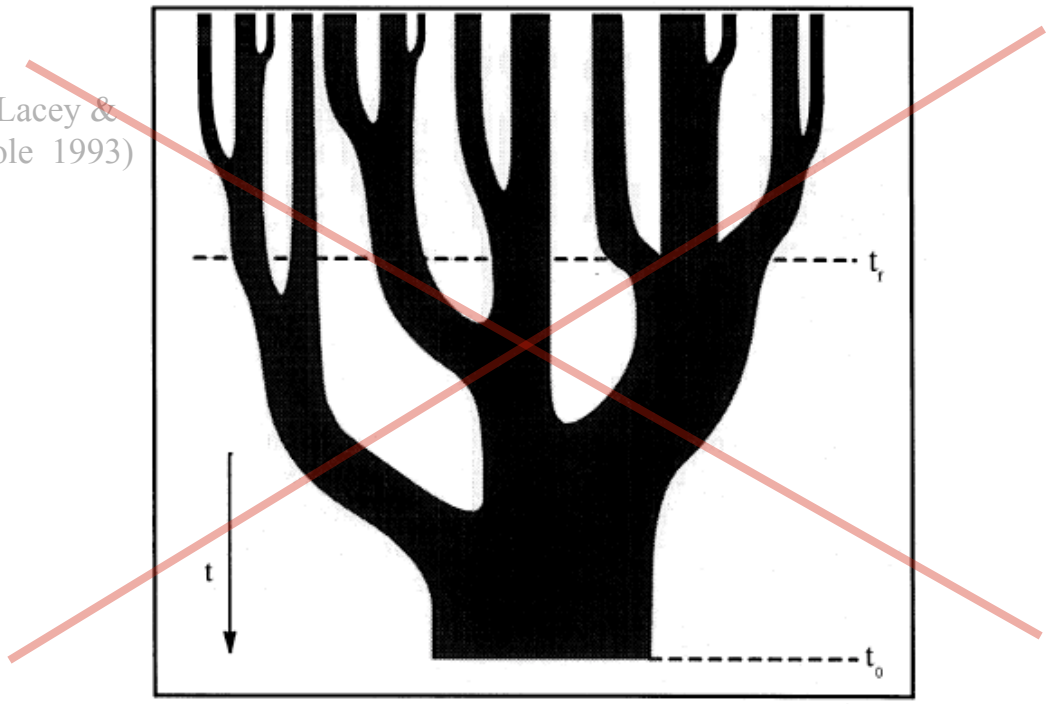
The *dual dwarf galaxy theorem* is violated
by the real universe and
thus the standard model of cosmology is falsified :

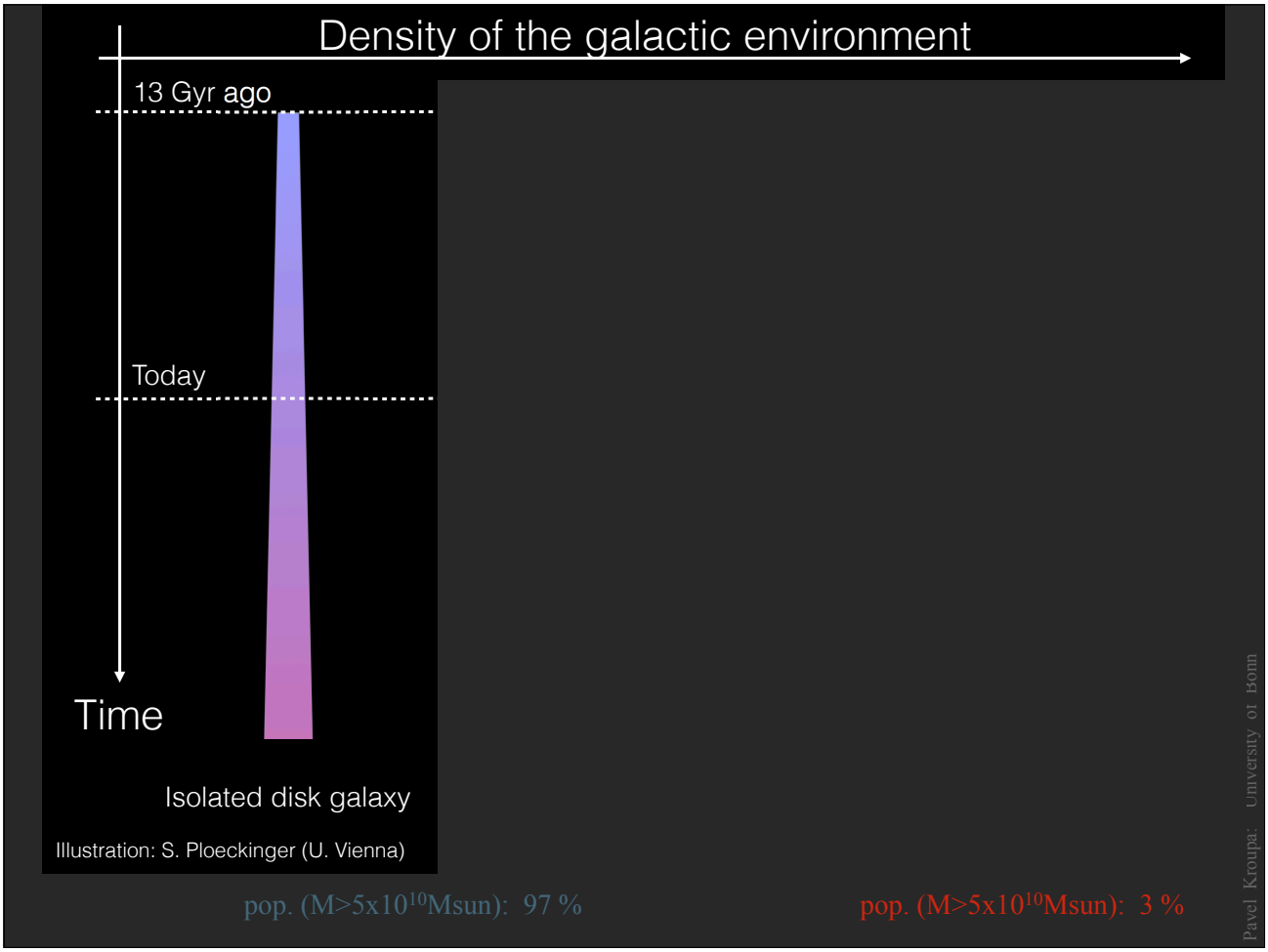
Dynamically relevant dark matter cannot exist in galaxies.
(The search for it will be fruitless).

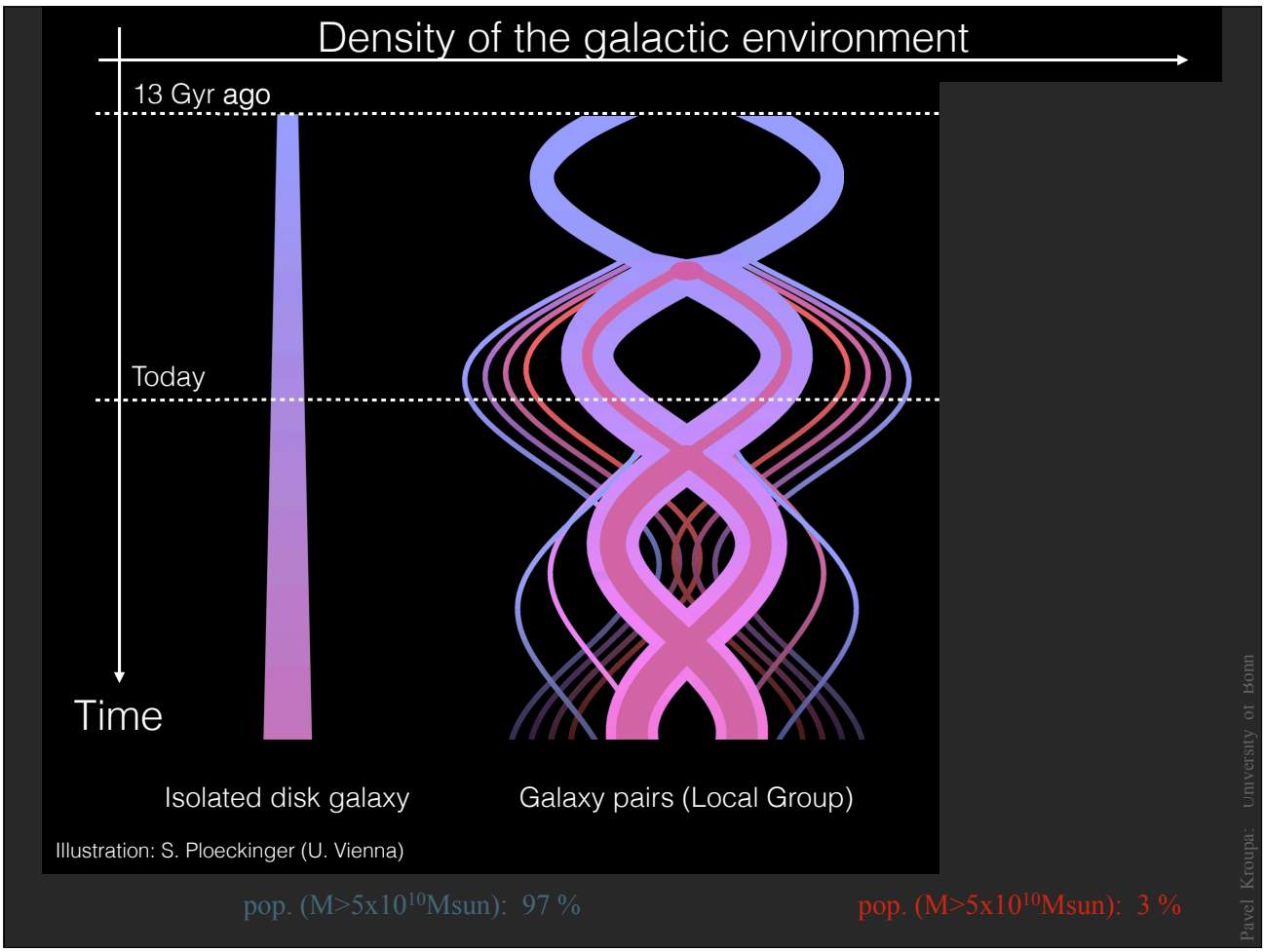
Effective dynamics ***is*** scale-invariant / Milgromian.
(i.e. "dark matter" ***must be mathematically equivalent*** to
Milgromian dynamics).

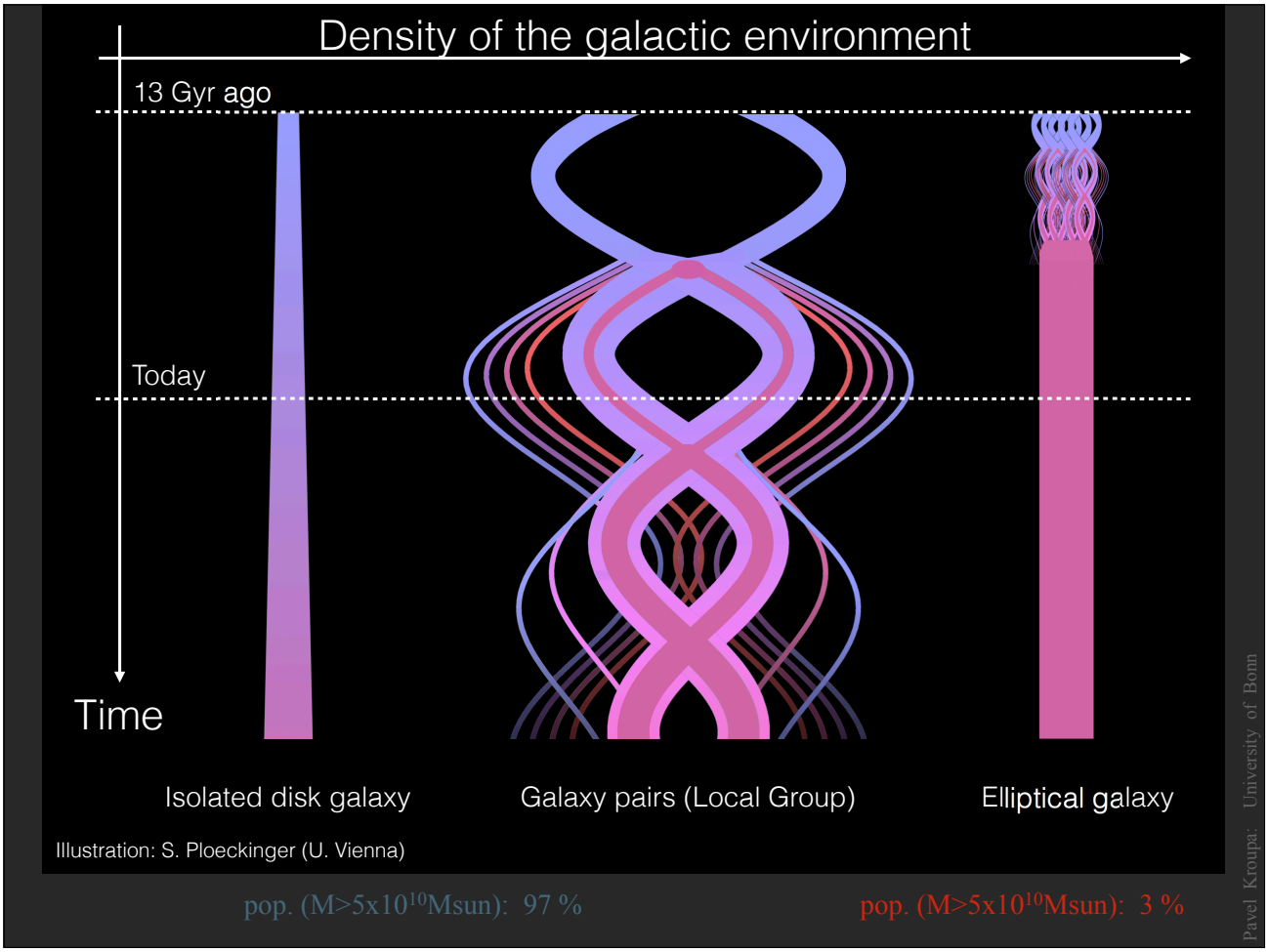
The Standard LCDM Model of Cosmology structure formation tree

(Lacey & Cole 1993)




Density of the galactic environment
13 Gyr ago
Today
Time
Isolated disk galaxy
Illustration: S. Ploeckinger (U. Vienna)
pop. (M>5x10^10Msun): 97 %
pop. (M>5x10^10Msun): 3 %
Pavel Kroupa: University of Bonn


Density of the galactic environment
13 Gyr ago
Today
Time
Isolated disk galaxy
Galaxy pairs (Local Group)
Illustration: S. Ploeckinger (U. Vienna)
pop. (M>5x10^10Msun): 97 %
pop. (M>5x10^10Msun): 3 %
Pavel Kroupa: University of Bonn



Conclusions

The *dual dwarf galaxy theorem* is violated by the real universe and thus the standard model of cosmology is falsified :

Dynamically relevant dark matter cannot exist in galaxies. (The search for it will be fruitless).

Effective dynamics ***is*** scale-invariant / Milgromian. (i.e. "dark matter" ***must be mathematically equivalent*** to Milgromian dynamics).

And galaxies merge rarely .

(Kroupa 2012)

Theorems:

Any realistic model of cosmology $\Rightarrow$ $\exists$ PDGs $\wedge$ TDGs

SMoC $\Rightarrow$ PDGs $\neq$ TDGs

PDGs $=$ TDGs $\Rightarrow$ ~~SMoC~~

Tests: (BTFR + R(M)R + DF)

Observations $\Rightarrow$ PDGs $=$ TDGs $\wedge$ ~~DF~~

$\Rightarrow$ ~~C/WDM~~

$\Rightarrow$ ~~SMoC~~

Consistency:

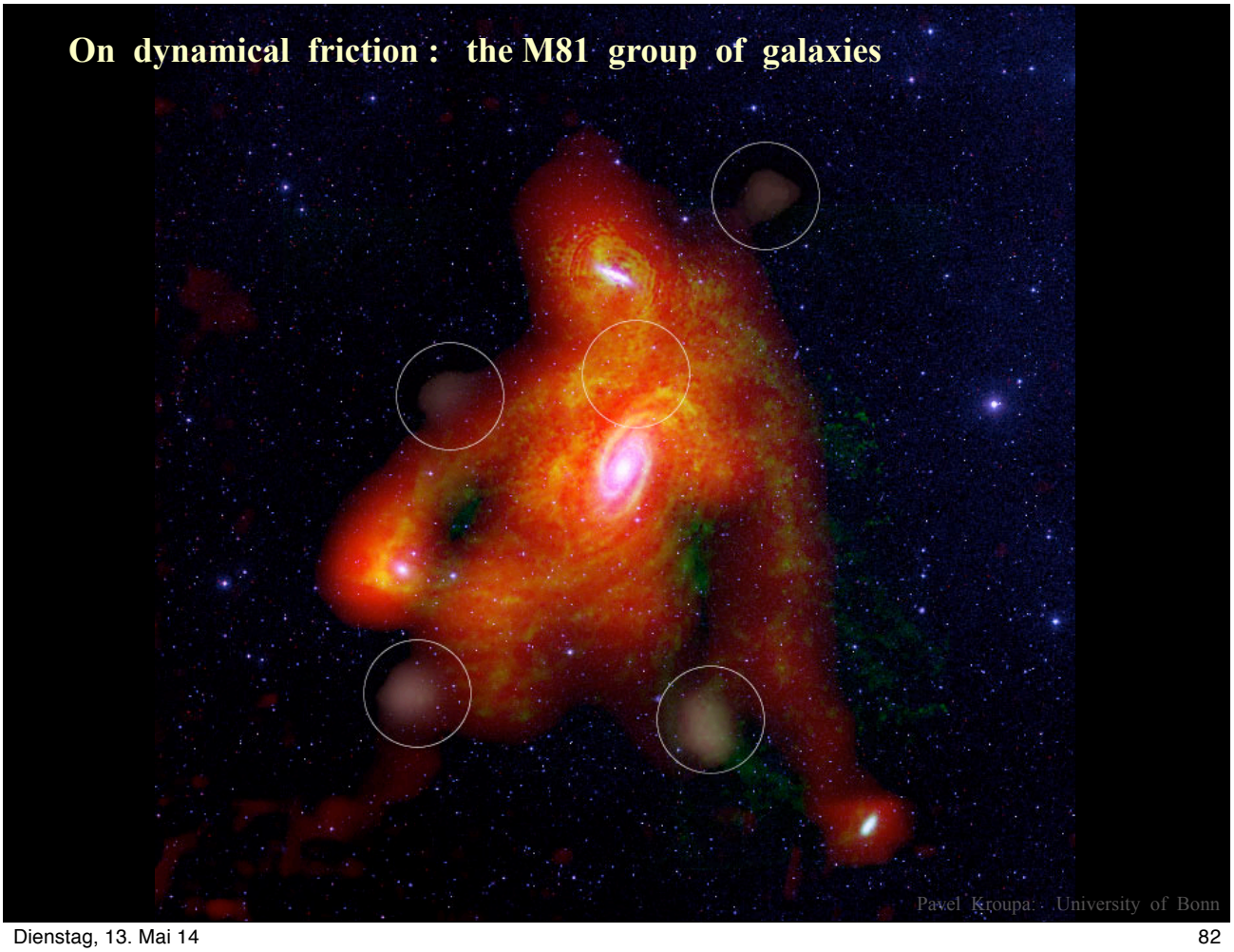
VPOS + GPoA $\Rightarrow$ ~~all satellite galaxies PDGs~~

VPOS + GPoA $\Rightarrow$ most/all satellite galaxies TDGs

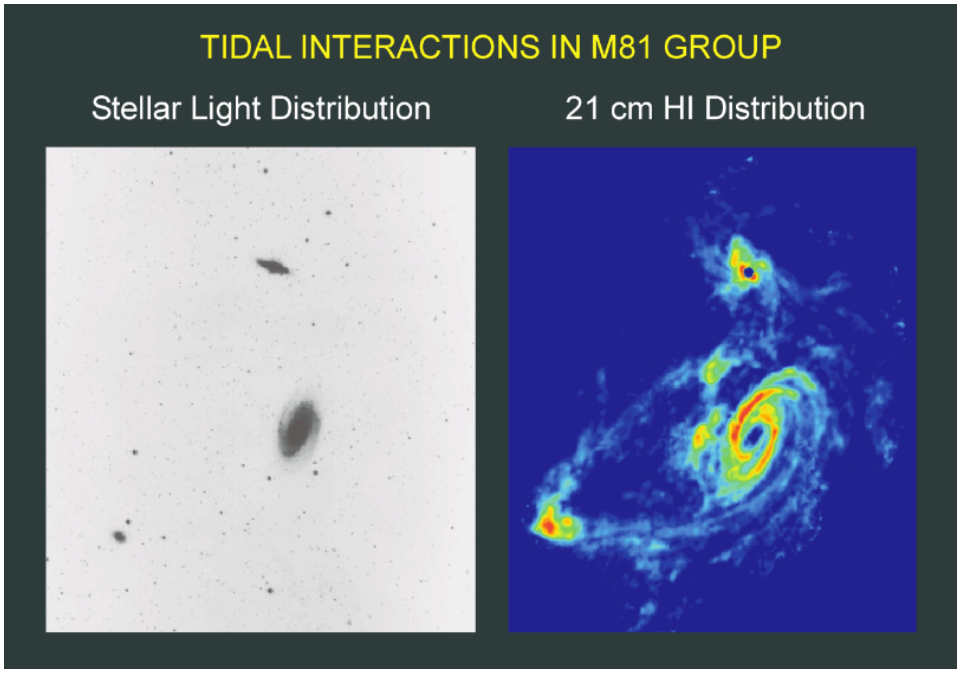
high M/L $\Rightarrow$ non-Newtonian/Einsteinian gravitation

Theory confidence graph

DM halo merger statistics vs fraction of E galaxies and bulgeless disk galaxies



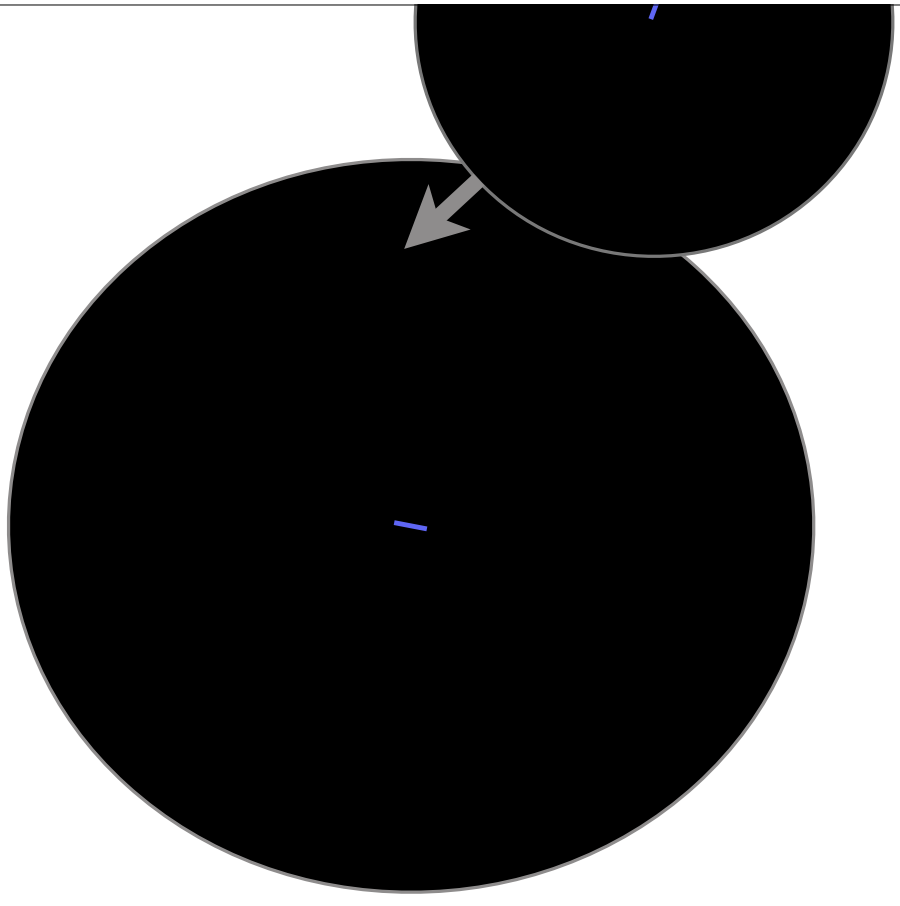
On dynamical friction : the M81 group of galaxies

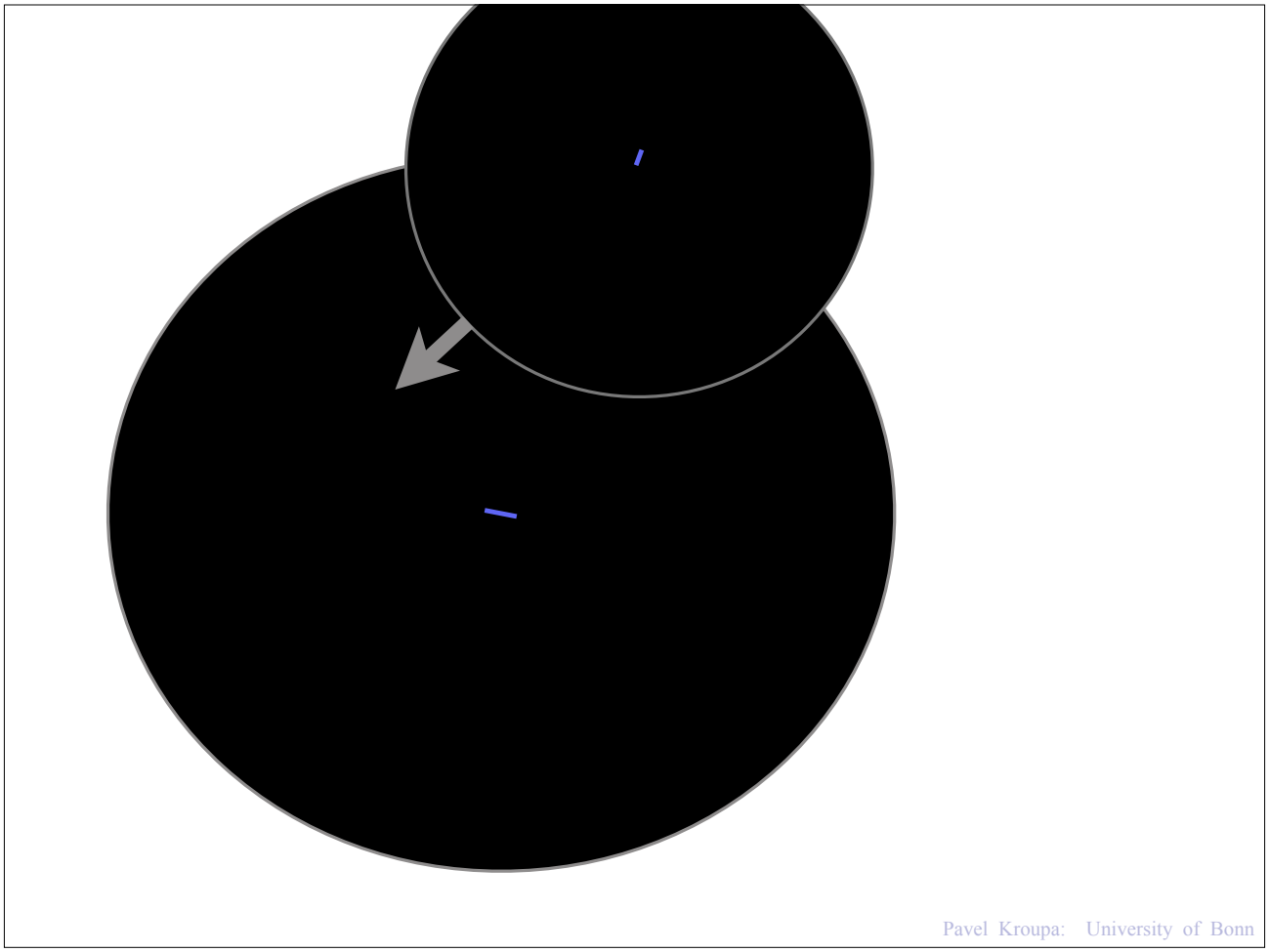


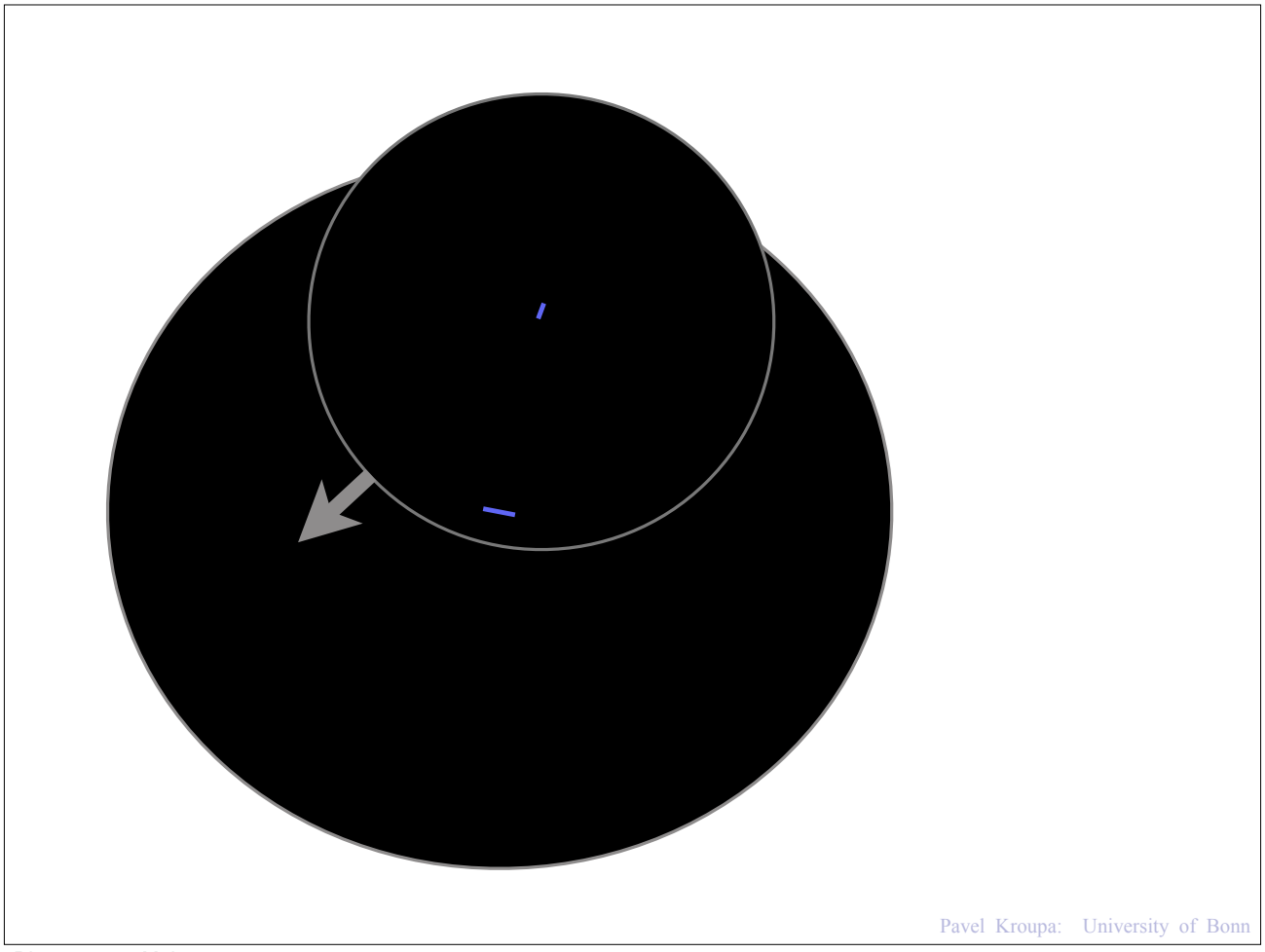
Last publications (conference proceedings only) :

Yun 1999 => no solutions with dark matter : system merges

Thomson, Laine & Turnbull 1999 => no solutions with dark matter : system merges







Galaxy populations do not work unless dynamical friction on dark-matter is turned off :

Only 3 % of all galaxies (Mstellar > 10^10 Msun) are E galaxies (Delgado-Serrano et al. 2010)

Too many (>50%) massive disk galaxies w/o classical bulges / but they must have formed through mergers (via the merger tree) (Kormendy et al. 2010)

In modelling the galaxy population over cosmic time dynamical friction must be artificially reduced (Shankar et al. 2014).

Galaxies form a tight main sequence at all redshifts (Speagle et al. 2014); i.e. no evidence for haphazard / stochastic merging (confirming Disney et al. (2008, Nature)

Hickson compact groups do not appear to merge (Pompei & Iovino 2003, 2010)

No solutions for MW satellites with proper motions if they have dark matter halos (dyn.fric. too efficient) (Angus et al. 2011)

Mergers in the SMoC

MW scale halo

Fakhouri et al. 2010 : 31 % have major mergers since z=1 (7-8 Gyr ago)

69 % have major mergers since z=3 (11-12 Gyr ago)

Stewart et al. 2008 :

Over past 10 Gyr : 95 % have a minor merger (accreting sub-halo with M>5x10^10 Msun)

Over past 10 Gyr : 70 % have a merger with M>10^11 Msun

Cox & Loeb 2008 : Major mergers destroy disks

Walker et al. 1996, Naab & Burkert 2003, Younger et al. 2007, Kazantzidis et al. 2009 :

Minor mergers (1:10) : growth of bulge and thickness of disk

This is at odds with population statistics :

97 % late-type galaxies. 3 % E galaxies, unchanged since past 6 Gyr

Delgado-Serrano, Hammer et al. 2010

. . .

Scale-invariant / Milgromian Dynamics (current best bet)

. . .

Milgromian Dynamics from quantum mechanical processes in the vacuum

Kroupa et al. (2010), Appendix A (see Milgrom 1999) :

". . . an accelerated observer in a de Sitter universe (curved with a positive cosmological constant Λ) sees a non-linear combination of the Unruh (1975) vacuum radiation and of the Gibbons & Hawking (1977) radiation due to the cosmological horizon in the presence of a positive Λ. Milgrom (1999) then defines inertia as a force driving such an observer back to equilibrium as regards the vacuum radiation (i.e. experiencing only the Gibbons-Hawking radiation seen by a non-accelerated observer).

Observers experiencing *a very small acceleration* would thus see an Unruh radiation with a low temperature close to the Gibbons-Hawking one, meaning that *the inertial resistance defined by the difference between the two radiation temperatures would be smaller than in Newtonian dynamics, and thus the corresponding acceleration would be larger*. This is given precisely by the formula of Milgrom (1983) with a well-defined transition-function $\mu(x)$, and $a_0 = c\,(\Lambda/3)^{1/2}$. Unfortunately, no covariant version (if at all possible) of this approach has been developed yet."

Milgromian Dynamics

Ansatz : (Milgrom 1983, ApJ, 270, 371)

$$\mu\left(\frac{a}{a_0}\right)\,\vec{a} = \vec{g_{\rm N}} \quad \begin{cases} \mu(x) = 1 \text{ if } |x| \gg 1 \\ \mu(x) = x \text{ if } |x| \ll 1 \end{cases} \qquad \text{i.e.} \quad \vec{a} = \vec{g_{\rm N}}\,\mu^{-1} \geq \vec{g_{\rm N}}$$

What is the interpretation ?

Milgromian dynamics can be understood to be

a different effective Law of Gravity
through a different "Poisson" equation

$$\vec{\nabla}\cdot\left[\mu\left(\frac{\left|\vec{\nabla}\phi\right|}{a_0}\right)\vec{\nabla}\phi\right] = 4\,\pi\,G\,\rho$$

giving the Milgromian potential

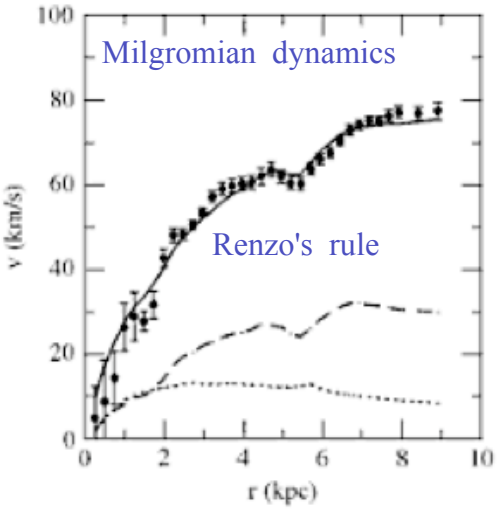
a modification of the Law of Inertia
through the breaking of the equivalence of inertial and gravitating mass

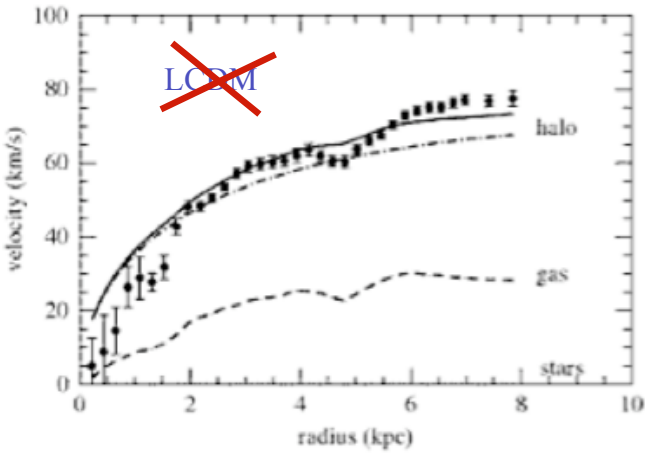
$$\vec{a} = \vec{F}\left[m\,\mu\left(\frac{\left|\vec{\nabla}\phi\right|}{a_0}\right)\right]^{-1}$$

where $\vec{F} = m\,\vec{g_{\rm N}}$ for gravity

Pavel Kroupa: University of Bonn

From Robert Sanders' Book
on
"*The Dark Matter Problem*",
Cambridge University Press, 2010





Pavel Kroupa: University of Bonn

In fact, given an *observed baryonic matter distribution*, the rotation curve

can be precisely predicted using Milgromian dynamics

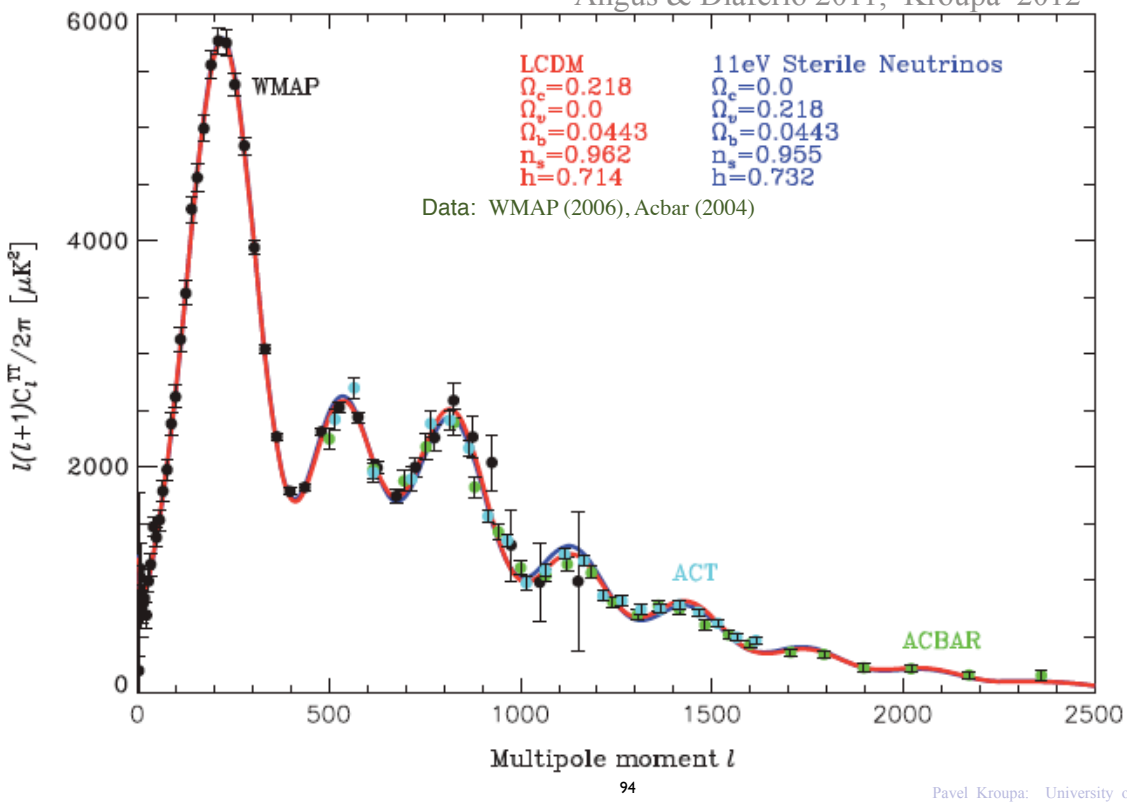
cannot be predicted using LCDM.

plus in Milgromian dynamics dark matter significantly reduced in galaxy clusters

→ (e.g. Sanders 2009 (review) : *"Modified Newtonian Dynamics : A Falsification of Cold Dark Matter"*)

CMB power spectrum in Milgromian dynamics

Angus & Diaferio 2011; Kroupa 2012



Thus,

The Concordance Cosmological Modell
does ***not uniquely***
account for the CMB nor for
Large Scale Structure.

In fact, with the falsification of the SMoC,
it has become irrelevant to ask whether any set of data
(e.g. large-scale structure or CMB)
fit the SMoC.