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Systems of magnetic binding of $10^{\sim 100}$ (e-p) pairs (or hydrogen atoms) are related to galaxies. Their rotation velocities are well described, yielding information on the mass, the average particle density and the damping of coherent rotation. Different from the mass estimate $M^{gr}\sim v_{max}^2 R/G_N$ derived from gravitation theory, the deduced galaxy masses show a rapid fall-off to smaller radii, which can be understood by the finiteness of these systems.

No evidence has been found for galactic dark matter contributions.

Keywords: description of gravitational systems as magnetic binding of many (e-p) pairs. quantitative account of the rotation profiles of galaxies, giving rise to masses in agreement with gravitation theory by including the finite size of these systems.

I. Introduction

Elementary bound or stationary states may be considered as the building blocks of nature, since they give rise to stability of matter over long periods of time. These systems require an equilibrium between binding and kinetic energy, governed by the virial theorem. Their description in form of atoms, hadrons, and leptons has been discussed recently [1, 2].

Galactic systems have also the important property of stability over long time scales. However, it appears to be difficult to consider these systems as bound states, since it is known that the universe is not of static structure: starting from a cosmic system, in which all matter had been confined in a small volume of high density, it expands permanently. In addition, for a realistic description of galaxies the origin of gravitation has to be understood.

Gravitation has been mostly described by Newton's gravitation theory, often complemented by Einstein's theory of general relativity [3]. In the latter, gravitation is considered as a deformation of space-time caused by massive objects. However, this theory is not satisfactory from a fundamental point of view: by eliminating gravity by the equivalence principle the real physical origin of the gravitational attraction rests unknown. Differently, in a (first-order) quantum theory similar to those applied to other fundamental forces, the extremely weak interaction has been tentatively interpreted [4] as tensor-exchange of "gravitons", but such spin=2 particles have not been found. Further, serious attempts have been made to describe gravity in high-dimensional string-type models [5], in which the notion of point particles is replaced by one-dimensional strings. However, these models have a very complicated structure with too many parameters to be adjusted. Also it is not clear, whether (and eventually how) curved space-time has to be included in a quantum description of gravity.

Important to note that all known theories applied to fundamental forces have been constructed empirically and need external parameters, which have to be fixed in some way. Also general relativity is an empirical theory, in which space-time parameters related to curvature, expansion, etc. have to be adjusted to astrophysical observations. But this does not allow absolute predictions, which can be tested experimentally. The requirement of an adequate fundamental theory can be expressed by the theorem: If in a theory adjustable parameters are needed, which cannot be determined from basic constraints, a (more) fundamental theory has to exist, in which all parameters can be deduced from first principles.

During the last years, such a self-contained theory has been developed [1, 2], in which atoms, but also hadrons and leptons can be understood without employing external parameters. One can also expect that such a fundamental theory can describe systems bound by gravitation. Indeed, in the study of magnetic bound states, a solution of two hydrogen atoms has been found [2], which has a tiny binding energy and a first order equivalent coupling constant in agreement

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with Newton's gravitational constant G_N. Therefore, this type of binding could be the origin of gravitation. To test this conjecture, in the present paper this formalism has been applied to the description of galactic systems.

First, we give a brief discussion of the theoretical framework with emphasis on basic boundary conditions. Then, a magnetic bound state composed of (e-p) pairs is discussed in detail, in which the parameter ambiguities could be removed by requiring a consistent account of the rotation velocity. Based on this fundamental system we describe galactic systems by a large number of such (e-p) pairs. In this way a complete and self-consistent description of galaxies is obtained.

II. Theoretical Background and Constraints on Magnetically Bound States

The present description is based on field theory, with a Lagrangian similar to that of quantum electrodynamics (QED), in which the fermions Ψ^+ and Ψ^- are accompanied by boson fields A_μ

$$\mathcal{L} = \frac{1}{\tilde{m}^2}(\bar{\Psi}^- D_\nu)\; i\gamma^\mu D_\mu\; (D^\nu \Psi^+) \;-\; \frac{1}{4}F_{\mu\nu}F^{\mu\nu}\;. \qquad (1)$$

The reduced mass $\tilde{m}$ is given by $\tilde{m}=m_1 m_2/(m_1+m_2)$, where m_i are the masses of the participating particles. The vector boson fields A_μ with coupling g to fermions are contained in the covariant derivatives $D_\mu = \partial_\mu - igA_\mu$. Further, the second term of the Lagrangian represents the Maxwell term with Abelian field strength tensors $F^{\mu\nu}$ given by $F^{\mu\nu}=\partial^\mu A^\nu - \partial^\nu A^\mu$, which gives rise to both electric and magnetic coupling (magnetic effects arise from the motion of fermions).

This framework has been discussed in detail in refs. [1, 2]. It leads to a theory of finite structure for radii $r\rightarrow 0$ and $r\rightarrow \infty$, giving rise to matrix elements, which can be described by fermion and boson wave functions $\psi_{s,v}(r)$ and $w_{s,v}(r)$ (of scalar and vector structure) connected by bosonic interaction potentials. For fermions this results in two matrix elements

$$\mathcal{M}^f_{ng}(r) = \bar{\psi}_{s,v}(r)\; V_{ng}(r)\, \psi_{s,v}(r)\; (v/c)^2\;, \qquad (2)$$

with n=2,3 and potentials of the form

$$V_{2g}(r) = \frac{\alpha^2(\hbar c)^2(2s+1)}{8\tilde{m}}\;\Big(\frac{d^2 w_s(r)}{dr^2} + \frac{2}{r}\frac{dw_s(r)}{dr}\Big)\frac{1}{w_s(r)} + E_o \qquad (3)$$

with s=0 for scalar and s=1 for vector states, and

$$V_{3g}(r) = \frac{\alpha^3(\hbar c)}{\tilde{m}} \int dr'\; w_{s,v}(r')\; v_v(r-r')\; w_{s,v}(r')\;. \qquad (4)$$

The boson matrix element is of the form

$$\mathcal{M}^g(r) = \frac{\alpha^3(\hbar c)}{\tilde{m}}\; w_{s,v}(r)\; v_v(r)\; w_{s,v}(r)\; (v/c)\;. \qquad (5)$$

The geometric boundary conditions [1, 2] are satisfied by using $\psi_{s,v}(r) \sim w_{s,v}(r)$, with

$$w_s(r) = w_{s_o}\; exp\{-(r/b)^\kappa\} \qquad (6)$$

and

$$w_v(r) = w_{v_o}\; [w_s(r) + \beta R\; \frac{dw_s(r)}{dr}]\;. \qquad (7)$$

The normalization of $\psi_{s,v}(r)$ and $w_{s,v}(r)$ is obtained by requiring $4\pi\int r^2 dr\; \psi^2_{s,v}(r)=1$, $2\pi\int r dr\; w^2_{s,v}(r)=1$ and $\beta R=-\int r^2 dr\, w_s(r)/\int r^2 dr[dw_s(r)/dr]$. Further, $v_v(r)$ is a boson-exchange interaction, which has a radial form similar to $w_v(r)$. In addition, for magnetically bound systems (v/c) is the relative velocity of different fermion and boson components, see the details in ref. [2].

An important point is that a consistent description (in which about 10 constraints have to be fulfilled) can be obtained only [1], if the energy E_o in eq. (3) is set to zero. This indicates a coupling of the theory to the (absolute) vacuum of fluctuating boson fields, which allows creation of massless fermion-antifermion pairs during overlap of boson fields. These particles are immediately bound to form simple $q\bar{q}$ mesons, q indicating massless fermions (quantons).

The binding and kinetic energies have been calculated as given in refs. [1, 2]. The mass is defined by the absolute binding energies $M = |E_{2g}|+|E_{3g}|$, where E_{2g} and E_{3g} are the binding energies in $V_{2g}(r)$ and $V_{3g}(r)$, respectively.

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In addition to the geometric boundary conditions [1, 2] we require momentum matching between fermions and bosons

$$< q_g^2 >_{rec}^{1/2} + < q_f^2 >_{rec}^{1/2} = 0 \quad (8)$$

as well as energy-momentum conservation

$$[< q_g^2 >^{1/2} + < q_f^2 >^{1/2}] \ (v/c) + E_g - x \ M_f = 0, \quad (9)$$

where $x = \sqrt{2\tilde{m}/M_f}$ and (v/c) is taken as positive.

The momenta are given by $< q_g^2 > = < q_g^2 >_{rec}$ and $< q_{f_s}^2 > = < q_{f_s}^2 >_{rec}$, but for vector particles $< q_{f_v}^2 > = \int q^4 dq \ \psi_v(q) V_{3g}^v(q) / < q_{f_v}^0 >$, where the Fourier transformed quantities are given by $(\psi_v, V_{3g}^v)(q) = 4\pi \int r^2 dr \ j_1{}^2(qr)(\psi_v, V_{3g}^v)(r)$.

Further, a mass-radius condition has been derived from the potential $V_{2g}(r)$

$$Rat_{2g} = \frac{(\hbar c)^2 \ (v/c)^2}{\tilde{m}(M_s/2) < r_{\psi_s}^2 >} = 1 \ . \quad (10)$$

Finally it is important to note that magnetically bound vector states (with radial node) are not stable. Nevertheless, energy-momentum conservation should be fulfilled for all states.

a) *Existence of a complex magnetic bound state*

A solution for magnetically bound hydrogen atoms (H-H) has been discussed in ref. [2], which led to a first-order equivalent coupling constant in agreement with Newton's gravitational constant G_N. Therefore, this type of bound state could be the origin of gravitation. However, in more detailed work it has been found that the boundary conditions are also satisfied, if both - the slope parameter b and the relative velocity factor $(v/c)^2$ - are multiplied with the same factor. This indicates that an extra constraint is needed to obtain an unambiguous solution.

Such a constraint can be defined by requiring that the velocity (v/c) is related to the kinetic energy by

$$(v/c) = \sqrt{\frac{2E^{kin}}{M_{tot}}} \ , \quad (11)$$

where $M_{tot} = 2m_e + 2m_p$ is the total mass of the diatomic H-H or $(e\text{-}p)^2$ state. By imposing this constraint, an unambiguous solution is obtained, in which all boundary conditions are satisfied, see table 1. Even for the s-state energy-momentum conservation is fulfilled for bosons and fermions separately. Important to note that also in this case the first-order equivalent coupling constant

$$\alpha_{gr} = \frac{\int V_{3g}^s(r) \ dr}{\int \frac{\hbar c}{r} \ dr} \quad (12)$$

Table 1: Solution of a $(e\text{-}p)^2$ state bound magnetically, using $\kappa = 1.35$ and $\alpha = 2.14$. All dimensional quantities are in GeV or fm.

system	$\tilde{m}$	b	$(v/c)^2$	$< r_s^2 >^{1/2}$	M_s	Rat_{2g}	α_{gr}
$(ep)^2$	0.469	0.3425	$1.51 \ 10^{-38}$	0.40	$2.6 \ 10^{-38}$	1.0	$5.9 \ 10^{-39}$

s	$< q_g^2 >^{1/2} (v/c)$	$< q_f^2 >^{1/2} (v/c)$	$\sum < q_{g,f}^2 >^{1/2} (v/c)$	E_g	xM_f	$xM_f - E_g$
0	$1.6 \pm 0.1 \ 10^{-19}$	$1.6 \pm 0.2 \ 10^{-19}$	$3.2 \pm 0.3 \ 10^{-19}$	$-1.6 \ 10^{-19}$	$1.6 \ 10^{-19}$	$3.2 \ 10^{-19}$
1	$2.2 \pm 0.2 \ 10^{-19}$	$4.2 \pm 0.3 \ 10^{-19}$	$6.4 \pm 0.5 \ 10^{-19}$	$-2.6 \ 10^{-19}$	$3.4 \ 10^{-19}$	$6.0 \ 10^{-19}$

is in good agreement with Newton's gravitational constant $G_N = 6.707 \ 10^{-39} (\hbar c) GeV^{-2}$. This result may be taken as convincing evidence that the origin of gravitation is magnetic binding of many atoms.

The deduced scalar density and potentials are shown in fig. 1. In the upper part, the present interaction $v_v(r)$ is compared to a gravitational potential ~1/r, which shows the difference between a finite interaction and a divergent one. Below, the scalar density $w_s^2(r)$ and the potentials $V_{3g}^{s,v}(r)$ are given. One can see that $V_{3g}^v(r) \sim w_s^2(r)$, as required from a second geometric boundary condition [1, 2]. In the lower part of the figure the potential $V_{2g}(r)$ is displayed, which stabilizes the system. This potential has the same radial form as the "confinement" potential in hadrons and leptons.

This solution shows a fermion root-mean-square (rms) radius of 0.40 fm, indicating that the protons and electrons come close to each other (giving rise to a $(e\text{-}p)^2$ rather than a diatomic H-H state). This is consistent with the general observation from hadrons and leptons that magnetically bound systems have smaller radii than those bound electrically. Another point of interest, the ambiguity between b and $(v/c)^2$ without applying the condition (11) - indicates that the first-order equivalent coupling constant α_{gr} is the same - and thus universal - for all gravitational systems with increased or decreased central density relative to the basic $(e\text{-}p)^2$ state.

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b) *Description of magnetic (gravitational) states of many (e-p) pairs*

In the following, systems composed of many (e-p) pairs are discussed. These objects have to fulfill also boundary conditions concerning geometry, momentum and energy-momentum conservation. The geometry requires similar radii of the boson and fermion distributions

$$< r_f^2 >_{gal}^{1/2} \sim < r_g^2 >_{gal}^{1/2} \sim N_{gal}^r < r_{g,f}^2 >_s^{1/2} \quad (13)$$

where $< r_{f,g}^2 >_{gal}^{1/2}$ are the fermion and boson rms-radii of the composite systems and $< r_{g,f}^2 >_s^{1/2}$ the corresponding radii of the basic (e-p) pair. Further, momentum matching

$$< q_g^2 >_{gal}^{1/2} = < q_f^2 >_{gal}^{1/2} \quad (14)$$

as well as energy-momentum conservation should be satisfied. For bosons this reads

$$E_{gal}^g \sim (N_{gal})^3 < q_{g_s}^2 >^{1/2} (v/c) = (N_{gal})^3 E_s^g \,, \quad (15)$$

and for fermions

$$M_{gal}^f \sim (N_{gal})^3 < q_{f_s}^2 >^{1/2} (v/c)/x = (N_{gal})^3 M_s^f, \quad (16)$$

where N_{gal} is the average number of basic (e-p)^2 states in r-direction, which can be different from N_{gal}^r obtained from the geometrical relation (13), (v/c) the relative fermion velocity of the (e-p)^2 bound states, E_{gal}^g the boson binding energy, M_{gal}^f the mass and $x = \sqrt{2\tilde{m}/M_s^f}$, where m̃ is the reduced mass.

For a composite system of many particles the relation between potential and kinetic energy is non-trivial: an acceleration term for individual particles can be derived [6] from the Lagrangian (1), which allows to drive the random motion of the single particles to a coherent rotation of the whole system. In this case the kinetic energy will be lowered, the virial theorem is violated and leads to a collapse of the system[1].

However, formation of a stable system is possible under the special condition that also the magnetic (gravitational) attraction is reduced by the same amount. Such a lowering of the binding energy may be explained by assuming that a repulsive potential has been built up by the annihilation of matter during the former high density phase of the universe, from which all galactic matter originates.

The radial dependence of the rotation velocity of galactic systems may be calculated from a relation similar to eq. (11) by replacing the kinetic energy E_{gal}^{kin} by $N_{gal}\,(dE_s^{kin}(r)/dr\,)r_s$ and the (total) mass by $N_{gal}^r\, M_s$. In addition, we have to introduce a damping factor f_{damp}, which takes a reduction of coherent rotation into account. This yields

$$\frac{v_{rot}(r_{gal})}{c} = \sqrt{\frac{2\; dE_s^{kin}(r)\; r_s}{dr \quad M_s}\,\frac{N_{gal}}{N_{gal}^r}}\; f_{damp}\;, \quad (17)$$

where $dE_s^{kin}(r)/dr$ is the radial derivative of the kinetic energy of the magnetic state in sect. 2. a given by

$$\frac{dE_s^{kin}(r)}{dr} = 2\pi\psi_s^2(r)r^3\,\left(\frac{dV_{2g}(r)}{dr} + \frac{dV_{3g}(r)}{dr}\right). \quad (18)$$

The ratio $\delta_{gal} = N_{gal}/N_{gal}^r$ can be understood as the average rms-radius of the basic (e-p) pairs in the galaxy divided by the rms-radius of the free (e-p)^2 state. But δ_{gal} can be considered also as the normalized central density of the galaxy with respect to that of the free (e-p)^2 state. For $\delta_{gal} < 1$ the average density is smaller than the basic magnetic state, whereas $\delta_{gal} > 1$ would indicate a system of higher density. In this respect it is important to mention that also for systems with $\delta_{gal} \neq 1$ all constraints (13) - (16) have to be satisfied, and also the first-order equivalent coupling constant is unchanged (universality of G_N). Finally it is important to note that for $f_{damp} \neq 1$ the virial theorem is not fulfilled, for $f_{damp} < 1$ the system will be driven to increased radii.

A second condition requires that the maximum rotation velocity of galaxies is related to (v/c) of the fundamental state by

$$\frac{v_{max}}{c} = (v/c)\,\sqrt{N_{gal}}\; f_{damp}\;. \quad (19)$$

By the geometric relation (13) and eqs. (17) and (19) the parameters δ_{gal} and f_{damp} are fixed, leading to an unambiguous determination of the galaxy masses, see eq. (16).

Finally, galaxy masses have been estimated using an (empirical) relation between maximum rotation velocity and galaxy mass - derived from gravitation theory

$$M^{gr} = v_{max}^2 R/G_N\;, \quad (20)$$

where R is the radius at v_{max}. A comparison of the deduced masses with this estimate will be made below.

III. Rotational Velocities of Galactic Systems

Although many aspects of gravitation can be well understood within Newton's theory of gravitation, the observation of galactic rotation velocities has led in the past to misleading interpretations. In the solar system, the orbital velocities of the different planets follow closely a Keplerian $\sqrt{1/r}$ behavior, which can be derived directly from Newton's law $V_{grav} \sim 1/r$. However, such a rapid fall-off of the velocity as a

[1] The collapse of gravitational systems has been worried about already by I. Newton after formulating the gravitational potential, see also Bentley's paradox [7].

function of radius has commonly not been observed for galaxies. In contrary, for many galaxies velocities have been deduced, which increase from small radii towards the peripheral region. This fact has been interpreted as evidence for the existence of dark matter halos. There have been also alternative descriptions, e.g. by MOND [8], in which an empirical modification of Newtonian dynamics has been employed.

In the present formalism the rotation velocity has to go to zero for r → 0, a physical necessity for a system of finite density and interactions. This fact indicates clearly that the r-dependence of the velocity $v_{rot}(r) \sim \sqrt{G_N M/r}$, see eq. (20), can be only an approximation of the rotation velocities at larger radii.

In the upper part of fig. 2 the particle density and the potentials are shown for a galactic system with arms - radius of 3.2 kpc. The derived rotational velocity is given in the second part. One can see that the rotation curve starts from zero at r = 0 and reaches a maximum at a radius somewhat smaller than the rms-radius, then falls again to zero. A Keplerian $\sqrt{1/r}$ dependence is shown by dot-dashed line, which shows an unphysical divergence for $r \to 0$ and $r \to \infty$.

a) Fit of various galaxies with different radii and rotation velocities

In the lower part of fig. 2 a comparison of the calculated rotation curve is made with the rotation profile of the galaxy F583-1, which is typical of many low surface brightness galaxies [9]. By scaling the rotation curve in radius to the outside region, a reasonable fit is obtained with a rms radius of about 13 kpc (the deviations at smaller radii could indicate another galactic component of smaller radius). The results of the present analysis are given in table 2. The deduced mass of about 8 10^7 solar masses is two orders of magnitude smaller than estimated with the mass formula (20). Further, the deduced value of δ_{gal} of 0.015 indicates an average galactic density of about 70 times smaller than of the fundamental state. The damping factor of the rotation $f_{damp} \sim$ 0.1 may indicate that about 90 % of the kinetic energy is in the form of random motion, whereas only 10 % of E^{kin}_{gal} contributes to the coherent rotation of the galaxy.

Rotation profiles for three other galaxies are shown in fig. 3, the two dwarf galaxies Draco and Fornax, and the elliptic galaxy NGC 3379, with data from refs. [10, 11]. Both, Draco and Fornax have rather small radii of about 0.4 and 1.3 kpc, respectively, whereas NGC 3379 shows a rms-radius of about 9 kpc. Apart from an increase of the rotation curves at small radius, the data are well described with the parameters given in table 2.

Table 2: Results for the galaxies in figs. 2-4, with root mean square radii $< r^2_{gal} >^{1/2}$ in kpc, maximum rotation velocities in km/s and masses in units of solar masses (M_{sol} =1.11574 10^{57} GeV/c^2). In the last column, the masses are given using the gravitational mass formula (20).

System	$< r^2_{gal} >^{1/2}$	v_{max}	N_{gal}	δ_{gal}	f_{damp}	M_{gal} (M_{sol})	M^{gr} (M_{sol})
F 583-1	13.0	78	1.5 10^{34}	1.5 10^{-2}	0.099	8.0 10^7	6.6 10^9
Draco	0.37	12.6	1.2 10^{31}	4.2 10^{-4}	0.034	4.2 10^{-2}	4.9 10^6
Fornax	1.25	14.5	1.4 10^{32}	1.4 10^{-3}	0.090	6.3 10^1	2.2 10^7
NGC 3379	8.5	230	4.8 10^{33}	7.3 10^{-3}	0.032	2.7 10^6	2.9 10^{10}
UGC 128	40.0	135	1.4 10^{35}	4.5 10^{-2}	0.026	6.7 10^{10}	6.1 10^{10}
NGC 2403	15.2	136	2.0 10^{34}	1.7 10^{-2}	0.017	2.0 10^8	2.4 10^{10}
NGC 5371	16.0	200	3.0 10^{34}	2.4 10^{-2}	0.010	6.4 10^8	7.1 10^{10}
" (2)	65.0	200	3.7 10^{35}	7.4 10^{-2}	0.009	1.2 10^{12}	2.2 10^{11}

Rotation velocities of three further galaxies, UGC 128, NGC 2403 from ref. [9] and NGC 5371 with data from ref. [12], are given in fig. 4. These have rather large radii of about 40 kpc and 20 kpc, respectively, with results given also in table 2. For all three galaxies there are indications for inner-galactic contributions with a rms-radius smaller by a factor 5. For the galaxy NGC 5371 the deduced velocities do not decrease for radii larger than 30 kpc, which may indicate a large-radius component given by dashed line in fig. 4, leading to the results marked (2) given separately in table 2.

The systematic behavior of the maximum rotation velocity and the extracted values of δ_{gal} and f_{damp} as a function of the galaxy mass is given in fig. 5, the galaxy masses as a function of radius are shown in fig. 6. Surprisingly, the deduced values of δ_{gal} (in the middle part of fig. 5) as well as the radius (in the lower part in fig. 6) show a very smooth mass dependence. Differently, v_{max} and f_{damp} show deviations from the average behavior, with values of f_{damp}, which follow closely the deviations of v_{max} from the solid line (for the Galaxy NGC 3379 results for a lower value of v_{max} of

75 km/s are shown by open squares, which give a slightly larger mass of 6.1 10^6 M_{sol} , but f_{damp} reduced to 0.026). The larger values of f_{damp} could be related to uncertainties in the extracted absolute velocities, but more likely due to another galaxy component with increased radius (similar to that assumed for the galaxy NGC 5371).

Of large importance, in all cases the value of f_{damp} is significantly smaller than 1. This may indicate that only the compact galaxy fragments participate in a coherent rotation, whereas the motion within these fragments is quite random. Further, f_{damp} may include a damping due to interactions with other galaxies or galactic matter. Since the present results yield $f_{damp} <$ 1, galaxies cannot be considered as real bound states: their radii increase permanently, in overall agreement with the observed expansion of the universe.

A really striking result is that the relative density $\delta_{gal} = N_{gal}/N^r_{gal}$ and the other quantities in fig. 5 show (after corrections, as discussed above) a very smooth mass dependence. Such a regular behavior can be expected only, if all galaxies originate from the same source, an early cosmic state of high density. An average value of δ_{gal} of 10^{-2} corresponds to a system, in which the rms-radius of the basic (e-p) pairs is increased to 40 fm, but this is still more than a factor 10^3 smaller than the size of hydrogen atoms. If we assume that galaxies are mainly composed of hydrogen atoms, its average density is rather high. This supports again the conclusion that galaxies have been created during the high-density phase of the cosmic evolution.

IV. Discussion

The analysis of galactic systems has shown that gravitation can be well described by magnetic binding of many (e-p) pairs (or hydrogen atoms). The following points are of particular interest:

a) *Constraints on the cosmic high-density phase of matter*

As discussed above, for the description of the rotation velocities of galaxies assumptions had to be make on the annihilation mechanisms of matter, which took place during the cosmic phase of high density. In radial direction, annihilation gave rise to an enormous flow of photons, resulting in heating the surrounding matter (transformation of kinetic energy in random motion) with subsequent disintegration into countless fragments of matter, from which galactic objects have been formed. However, in the galaxy fragments the kinetic energy is essentially due to random motion.

In transverse direction, annihilation photons could not be produced; instead a repulsive potential (opposite in sign to a binding potential) has been built up, which led to a reduction of binding, responsible for the generation of rather stable galaxies.

b) *Relation between fundamental description and first-order theories*

A surprising result of the present study is that for large galaxies the extracted masses are in rather good agreement with those obtained by using the gravitational mass formula (20). At first sight, this agreement appears to be accidental, if one considers the different mechanisms involved in the present analysis. However, one should realize that the present theory is based on the Lagrangian (1), which is an extension of the first-order Lagrangian of QED, see ref. [1]. By assuming $D_\nu D^\nu =$ 1 the QED Lagrangian is restored, which gives rise to a Coulomb potential $V_{coul} = \alpha\hbar c/r$ and the correct binding energies of atomic states. As detailed in ref. [13], these binding energies are also reproduced in the present theory, but in a rather complicated way including many s- and p-states, which satisfy a linear quantum condition on the radius. In addition, the electric fine-structure constant $\alpha \sim$ 1/137 is reproduced by the sum of first-order equivalent coupling constants α^n_{eq}.

For gravitation this appears to be similar, assuming $D_\nu D^\nu$= 1 leads to a first-order theory, which can be considered as a quantum description of Newton's theory of gravitation, which gives rise to a gravitation potential $V_{grav}(r) = \alpha_{gr}\ \hbar c/r$ with a coupling constant $\alpha_{gr} \simeq G_N\, m_1 m_2/\hbar c$. So, it is conceivable that also other features of Newton's theory of gravitation are recovered, as masses. This is confirmed for large galaxy masses by the present results.

However, as shown in the lower part of fig. 6, a strong fall-off of the deduced masses is obtained for decreasing radii, which is not found in the gravitational mass formula (20). This behavior can be well understood by the finiteness of the interaction $v_v(r)$, as shown in fig. 6. In the upper part the r-dependence of the Fourier transformed interaction $v_v(q)$ is compared to that of the gravitational potential $V_{grav}(q) \sim 1/q^2$. For small values of *r* (or *q*) the interaction $v_v(q)$ stays finite, whereas $V_{grav}(q)$ goes to infinity. The ratio $v_v(q)/V_{grav}(q)$ as a function of *r* drops to zero for *r* → 0, as shown by the solid line.

Exactly this behavior is observed in the galaxy masses, see the lower part of fig. 6. By scaling the radii and momenta to the corresponding radii and masses of galaxies, the masses from gravitation theory (open squares) can be fitted by a function $m^{gr} \sim V_{grav}(q)$ $q^{2.5}/V_{grav}(q)$ (given by the dot-dashed line). By multiplying m^{gr} with the ratio $v_v(q)/V_{grav}(q)$ given in the upper part, the solid line is obtained, which yields a good description of the radius dependence of the deduced galaxy masses. This agreement indicates that the strong drop-off of the deduced galaxy masses for smaller radii is due to the finiteness of the system.

c) Evidence for dark matter?

An important topic, discussed extensively in the literature, is the possible existence of dark matter, which does not couple to known particles by electromagnetic forces. Corresponding particles have been proposed based on conclusions drawn from current particle theories [4], but the need for dark matter is also a requirement from general relativity. Therefore, large efforts have been made to detect these particles. Up to date the only experimental indication for the existence of dark matter comes from a comparison of observed galactic rotation velocities with Keplerian $\sim\sqrt{1/r}$ rotational curves, from which the possible existence of dark matter halo contributions has been inferred, see e.g. in ref. [14]. Based on the present results in sect. 3, however, such an interpretation should be abandoned.

A similar conclusion has been drawn from MOND [8], in which an empirical modification of the Newtonian dynamics is employed. Also in this approach the rotation velocities decrease for small radii (as detailed above, the condition $v_{rot}(r)\rightarrow 0$ is a physical necessity for a finite system). This property gives rise to a finite range of the gravitational force, yielding a natural solution of Bentley's paradox [7].

Further, it should be mentioned that also direct searches for dark matter in particle physics experiments have given negative results. From extensions of current theories [4] the existence of super-symmetric or other exotic particles has been predicted as a source of dark matter. In particular, super-symmetry has been proposed as a mechanism to understand the flavour degree of hadrons and leptons. But this degree can be well understood in the present theory [15] without the assumption of additional fields.

d) Deflection of light

General relativity predicts a relation between space and time (space-time), which does not exist in the present framework. Evidence for this property stems from the bending of light from solar and galactic systems (lensing). However, in the present formalism the bending of light on massive systems can be described by the deflection of photons from multi-atomic systems. This is similar to Compton scattering from the electron (which is also a magnetically bound system [2]), but also to optical deflections and the scattering of nuclei. These processes can be described in partial wave expansions (with an incoming spherical wave and an interference of outgoing scattering waves). So, we expect that all properties of gravitation can be described in the present theory based on first principles.

V. Summary

The present study of systems bound by magnetic forces has shown that rotation curves of galaxies can be well understood in a self-contained and fundamental theory.

The results may be summarized as follows:

1. The fact that a stable (e-p)^2 system has been found with a first-order equivalent coupling constant in agreement with Newton's gravitational constant G_N can be taken as evidence that the origin of the gravitational force is magnetic binding of (e-p) pairs.
2. This conclusion is confirmed by the analysis of galaxy rotation, which is well described in the present approach. The strong reduction of the rotation velocities may indicate that galaxies have been formed from strongly heated matter during the high-density phase of the universe. The deduced galaxy masses are consistent with the empirical relation $M^{gr}\sim v_{max}R/G_N$, if finite size effects are taken into account.
3. The fact that all boundary conditions can be fulfilled only by assuming $E_o = 0$ in eq. (3) indicates a coupling of the theory to the (absolute) vacuum, by which matter in its simplest form could be created out of the vacuum during the genesis of the universe. However, in this way only particles with equal fermion and antifermion content could be generated. The breaking of this symmetry in the collapse of the generated matter - leading to the high-density phase of the universe - is one of the most challenging puzzles to be explained.
4. Finally, from a study of the complex structure of the Lagrangian (1) – including derivative terms with $\partial\Psi$ and $\partial^2\Psi$ - a better understanding of the dynamics of these processes may be obtained.

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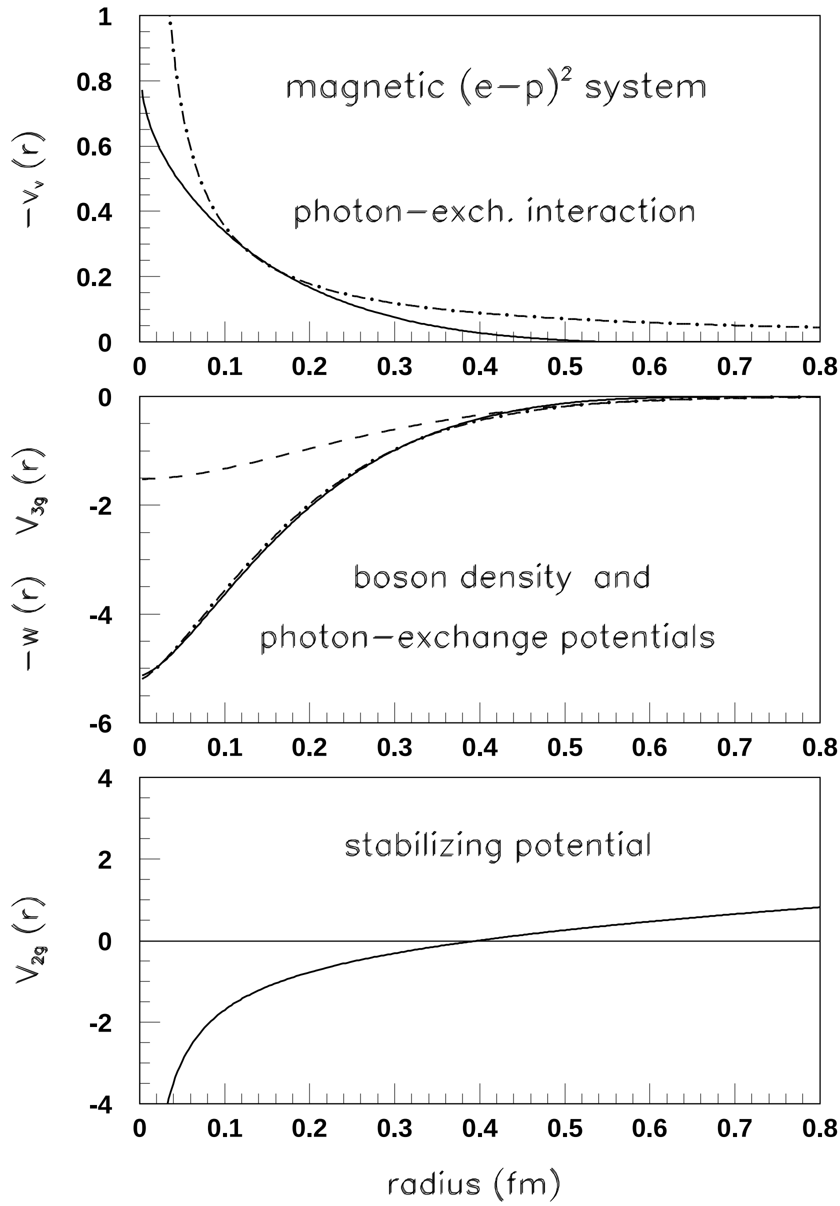

Figure 1: Radial dependence of scalar density and potentials of a magnetically bound (e-p)[2] state with a root mean square radius $< r_g^2 >^{1/2}$ of 0.4 fm. Upper part: Relative shape of the interaction $v_v(r)$, given by solid line, in comparison with the 1/r dependence of the gravitational potential (dot-dashed line). Middle part: Boson-exchange potentials $V_{3g}^{s,v}(r)$ and (negative) scalar boson density $w_s^2(r)$, given by dashed, solid and dot-dashed lines, respectively. Lower part: Stabilizing potential $V_{2g}(r)$.

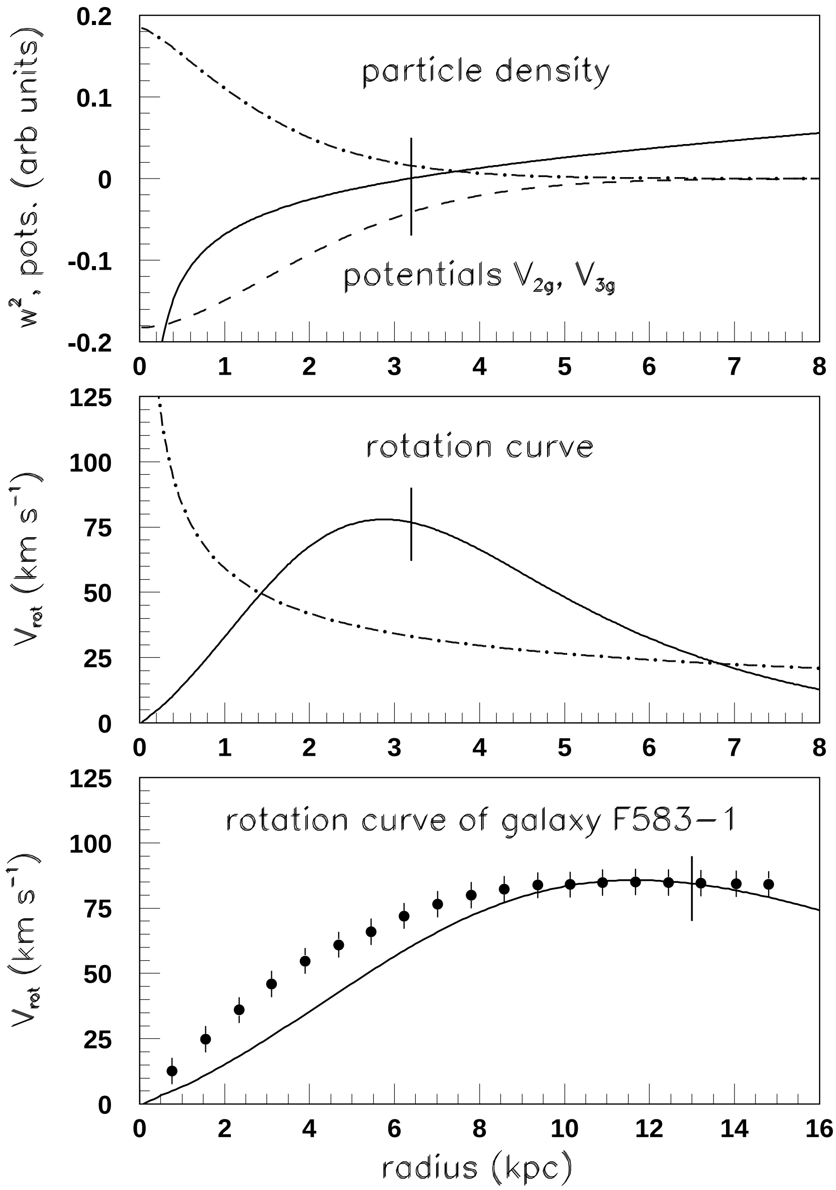

Figure 2: Upper part: Radial dependence of the density (dot-dashed line) and the potentials $V_{2g}(r)$ and $V_{3g}(r)$ of a galactic system with a rms-radius of 3.2 kpc, given by solid and dashed lines. Middle part: Deduced velocity distribution (solid line) in comparison to a Keplerian form (dot-dashed line), normalized to the same integral. Lower part: Velocity curve with radius fitted to the measured data of the galaxy F583-1 of ref. [9] (solid line). The vertical lines indicate the rms-radius of the density.

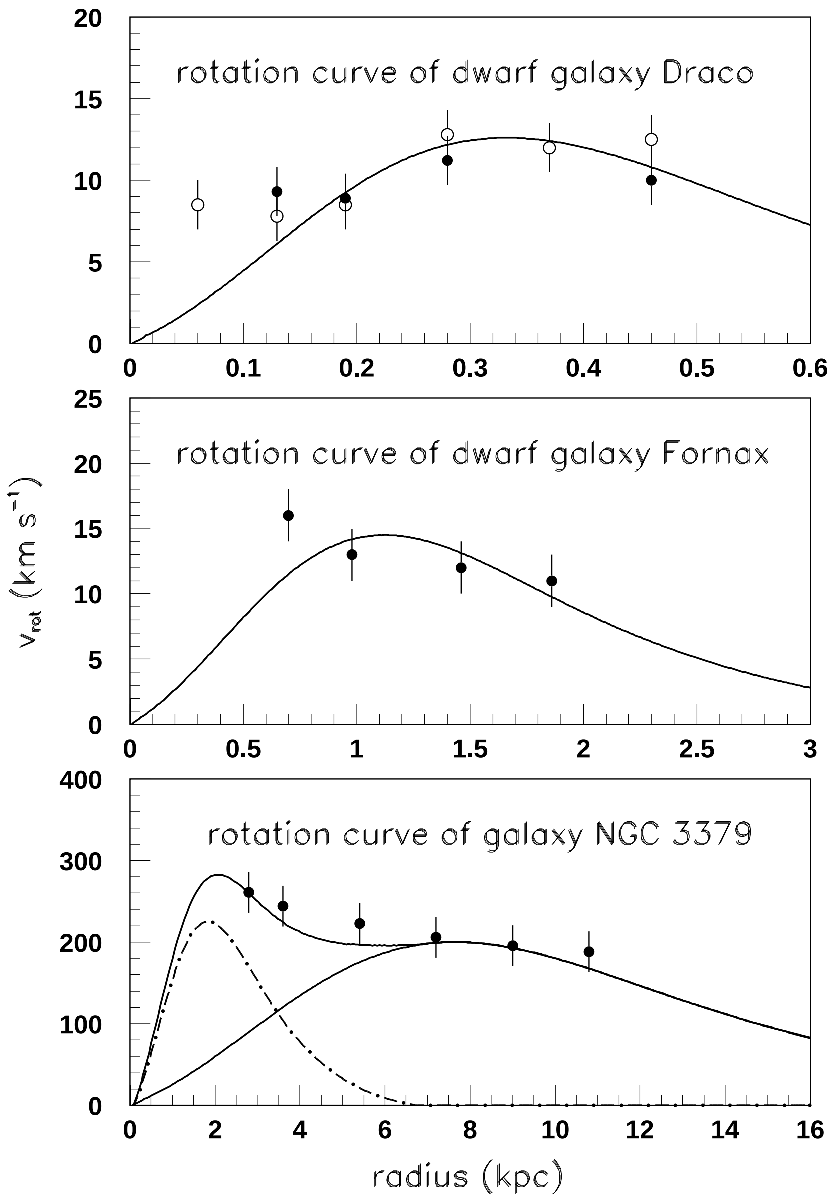

Figure 3: Radial dependence of the rotation velocities for the galaxies Draco, Fornax and NGC 3379 from ref. [10], for Draco see also ref. [11], together with rotation curves with the parameters in table 2. The increase in the rotation velocities at small radii, especially for NGC 3379, may indicate a second contribution with a radius smaller by a factor 4, shown by dot-dashed line.

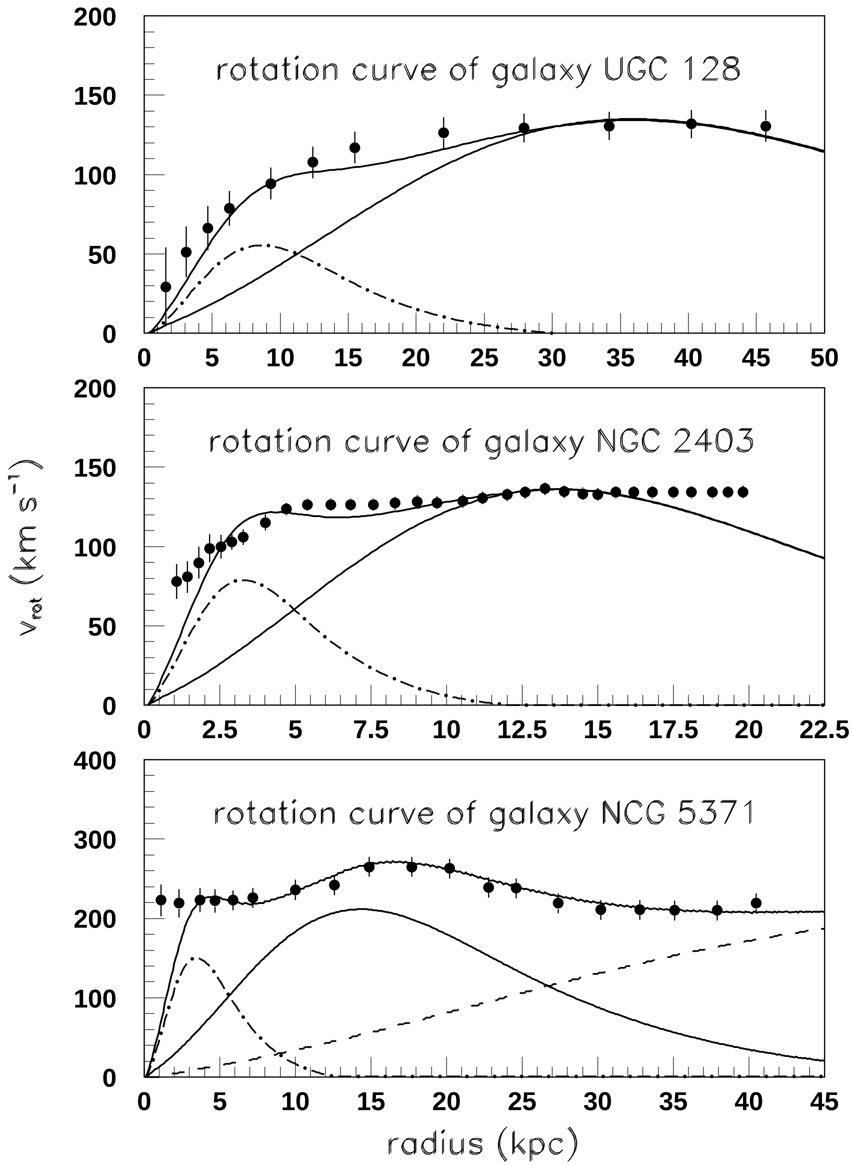

Figure 4: Rotation velocities for the galaxies UGC 128 and NGC 2403 from ref. [9], and NGC 5371 from ref. [12] as a function of radius, together with rotation curves with the parameters in table 2. The dot-dashed lines indicate a second component for each galaxy with a radius reduced to 24 %. An additional large radius component for NGC 5371 is given by dashed line.

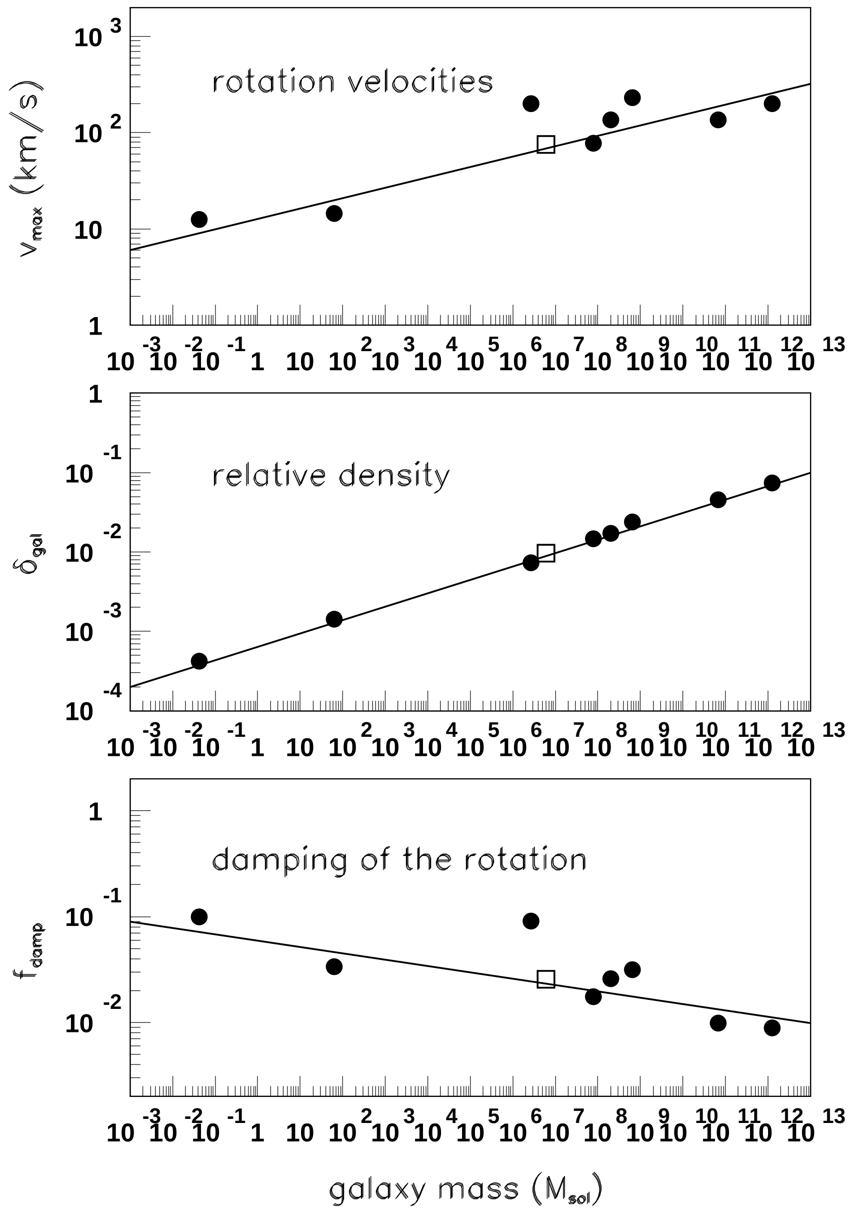

Figure 5: Mass dependence of the velocities v_{max} and deduced parameters δ_{gal} and f_{damp} for the galaxies in figs. 2-4, given by solid points. The solid lines show the average dependence of the different quantities. For the galaxy NGC 3379 the open squares are obtained by reducing v_{max} to 75 km/s, which gives a good agreement with the average dependencies given by solid lines.

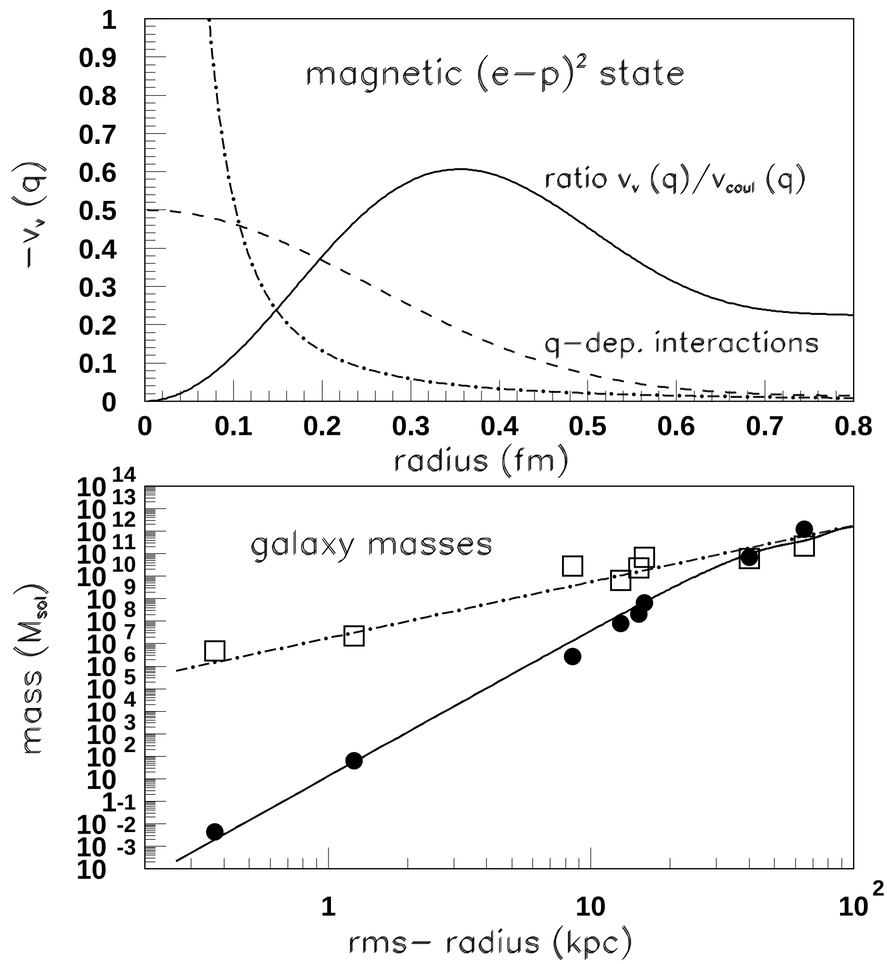

Figure 6: Upper part: Fourier transformed interaction vv(q) of the (e-p)^2 state in sect. 2.1 (dashed line), the gravitational potential $V_{grav}(q)$ (dot-dashed line) and the ratio $v_v(q)/V_{grav}(q)$ (solid line) as a function of radius. Lower part: Radius dependence of the deduced galaxy masses (solid points) and mass estimates using the gravitation mass formula (20) given by open squares. A fit of the latter is given by the dot-dashed line, whereas the solid line is obtained by multiplying this fit with the above $v_v(q)/V_{grav}(q)$ ratio.

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