Quasar Redshifts in Iso-Minkowski Spaces

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Abstract
We suggest a possible interpretation of the large redshifts of quasars in terms of a deformation of their interior metric, based on Santilli's Lie-isotopic lifting of special relativity. The Lie-isotopic Doppler effect is due to the inhomogeneity and anisotropy of the hyperdense quasar's atmosphere. Numerical estimates are derived from available astrophysical data, which indicate a possible revision of the speed of quasars with respect to the associated galaxy, while leaving current views on the expansion of the universe completely unaffected.

Key words: quasars, redshifts, deformed space-time

Soon after the discovery in 1963 of quasistellar sources (quasars),[1] a debate arose about their cosmological nature. Indeed, it is well known that they exhibit very large redshifts $(0.1 < z < 5)$. If, as usual, one assumes that the redshift has a cosmological origin, then, according to Hubble's law, quasars must be at tremendous distances from us. This poses serious problems in explaining their consequent enormous emissions of energy.[1,2] Moreover, in some cases the nucleus of a quasar consists of two components which (if quasars are very distant) appear to recede from each other with relative speed much greater than the velocity of light.[3]

Because most of the difficulties encountered in the explanation of quasar properties arise from the cosmological interpretation of their large redshifts, attempts have been made to circumvent them by a "nearby" localization of quasars. Such a "local" hypothesis has appeared as early as 1966 by Hoyle and Burbidge[4] and, subsequently, was strongly supported by Arp.[5] However, standard noncosmological interpretations of the quasar redshifts are all imperfect (for instance, their gravitational explanation clashes with stability problems, due to the strong gravitational fields needed to create them).[2] Therefore, in order to uphold a noncosmological hypothesis of origin of the quasar redshifts, one is forced to invoke a breakdown in quasars of conventional physical laws.

In this paper we shall apply to the quasar's redshift, apparently for the first time, Santilli[6,7] a hypothesis, according to which, in the transition from motion in the homogeneous and isotropic vacuum (Einsteinian conditions) to motion within inhomogeneous and anisotropic atmospheres (non-Einsteinian conditions), light experiences a redshift described by a certain geometrical modification (called "mutation") of the Minkowski space-time (see below). The main aspect we shall investigate in this paper is therefore the possibility that the currently measured quasar redshifts may be partially due to the propagation of light within the quasar's hyperdense, inhomogeneous, and anisotropic atmosphere.

In essence Santilli first showed[6] that the quasar's atmosphere can be quantitatively described by a mutation $\hat{g} = Tg$ of the Minkowski metric $g = \mathrm{diag}(-1, 1, 1, 1)$ induced by a positive-definite element $T > 0$ (called an "isotopic element") which describes precisely the inhomogeneous and anisotropic character of the hyperdense quasar atmosphere. In turn, this implies a Lie-isotopic generalization of the Lorentz symmetry constructed with respect to the generalized unit $I = T^{-1}$. This implies a step-by-step generalization of special relativity. Santilli included these studies in a detailed treatment in Ref. 7, where it was shown that, besides representing the global effect of the propagation of light within inhomogeneous and anisotropic media via a suitable selection of T (see below), the Lie-isotopic theory can also represent the physically different case of extended-deformable particles under the contact, nonlinear, nonlocal, and nonpotential interactions caused by motion within physical media, and a number of other non-Einsteinian conditions. Santilli then completed his studies in the recent monographs.[8] Independent reviews have appeared in Ref. 9.

To avoid possible misrepresentations, it should be noted that Santilli's Lie-isotopic theory describes physical conditions (inhomogeneous and anisotropic geometries, nonlocal and non-Hamiltonian interactions, etc.) under which special relativity is clearly *inapplicable* (and not "violated"). Also, the emerging generalizations encompass special relativity because (1) they are based on structurally more general mathematics (the Lie-isotopic generalization of Lie's theory); (2) they represent physical conditions fundamentally more general than those of special relativity (motion of extended-deformable particles or of electromagnetic waves within physical media); and (3) they include special relativity as a particular case for $T = 1$.

Santilli[6] originally proposed the names "Lorentz-isotopic transformations" for the new symmetries and "Lorentz-isotopic relativity" for the emerging new relativity. However, these new structures are now called "Lorentz-Santilli transformations" and "Santilli's special relativity."

Let us briefly summarize the main foundation of Santilli's generalization of special relativity to the readers not acquainted with it. The basic idea is that in transition from empty space (exterior, Hamiltonian dynamics) to a physical medium (interior, non-Hamiltonian dynamics), the Minkowski space-time $\mathcal{M}(x, g, \mathcal{R})$ is changed ("mutated") to an isotopic Minkowski space $\hat{\mathcal{M}}(x, \hat{g}, \hat{\mathcal{R}})$ (Santilli space of class I):

$$\hat{\mathcal{M}}(x, \hat{g}, \hat{\mathcal{R}}) : \hat{g} = Tg; \quad g = \mathrm{diag}(-1, 1, 1, 1),$$

$$T = \mathrm{diag}(b_0^2, b_1^2, b_2^2, b_3^2), \; b_\mu^2 > 0 \tag{1}$$

where the local coordinates x are conventional, and $\hat{\mathcal{R}}$ is the isofield of isonumbers[1]:

$$\hat{\mathcal{R}} = \{\hat{a} | \hat{a} = a\hat{1}, \; a \in \mathcal{R}, \; \hat{1} = T^{-1}\}. \tag{2}$$

In general, the interior metric (and therefore the b_μ's) depend (in a generally nonlinear, nonlocal, or other functional way) on the coordinates x, the velocities $\dot{x}$, the index of refraction n, the density μ, the temperature τ, and any needed additional quantity (such as accelerations $\ddot{x}$, etc.):

$$\hat{g}_{\mu\nu} = \hat{g}_{\mu\nu}(x, \dot{x}, \ddot{x}, n, \mu, \tau, \ldots). \tag{3}$$

A few comments are in order. First, let us stress that the deformation of the metric has nothing to do with gravitation.[2] It merely represents a geometrization of the physical medium that describes, on average, the effect of nonpotential, non-Hamiltonian forces on a test particle, and, for the different case of propagation of electromagnetic waves, the geometrical implications of the inhomogeneity and the anisotropy of the medium in which propagation occurs. The meaning of the coefficients b_μ is then easily seen by considering the generalized interval

$$\hat{x}^2 = x^\mu \hat{g}_{\mu\nu} x^\nu = x_1^2 b_1^2 + x_2^2 b_2^2 + x_3^2 b_3^2 - c_0^2 b_0^2 t^2. \tag{4}$$

It is therefore easily realized that the generalized quantity $c = b_0 c_0$ (with c_0 being the usual light speed in a vacuum) represents the speed of light in the physical medium considered (assumed to be transparent).[3] In this case we have the simple geometric interpretation $b_0 = 1/n$, where n is the index of refraction. The space elements $\hat{g}_{ii} = b_i^2$ have similar interpretations: they represent the inhomogeneous and anisotropic character of the physical medium in which motion occurs. It is therefore clear that there exist infinitely many isotopes of the Minikowski space (corresponding to the infinitely many different interior physical media).

Let us now discuss the problem of the quasar redshifts. We assume that (because of the presence inside quasars of non-Hamiltonian forces; we shall come back to their possible origin later) the quasar atmosphere can be considered as an anisotropic and inhomogeneous medium and therefore described by an isotopic Minkowski space-time of the kind (1), with metric tensor[4]:

$$\hat{g}_{\mu\nu} = \mathrm{diag}(-b_0^2, b_1^2, b_2^2, b_3^2). \tag{5}$$

The corresponding Lorentz-Santilli transformations (for a boost, say, along the third axis) read[6-8]

$$\begin{aligned} x_1' &= x_1, \\ x_2' &= x_2, \\ x_3' &= \hat{\gamma}(x_3 - \hat{\beta} x_0), \\ x_0' &= \hat{\gamma}(x_0 - \hat{\beta} x_3), \end{aligned} \tag{6}$$

where

$$\hat{\gamma} = (1 - \hat{\beta}^2)^{-1/2}; \quad \hat{\beta} = Vb_3/c_0 b_0 = \beta b. \tag{7}$$

and $\beta = V/c_0$ is the usual velocity parameter, and we put

$$b = b_3/b_0. \tag{8}$$

Then Santilli's iso-Doppler formula[7] holds:

$$\omega' = \omega\hat{\gamma}(1 - \hat{\beta}), \tag{9}$$

whence one immediately gets the *Lie-isotopic expression for the redshift*:

$$\hat{z} = \frac{\hat{\lambda} - \lambda_0}{\lambda_0} = \left(\frac{1 + \hat{\beta}}{1 - \hat{\beta}}\right)^{1/2} - 1. \tag{10}$$

which is proposed in this paper apparently for the first time.

It is now easily seen that due to the presence of the geometrical parameter b, the *apparent* behavior of the quasar corresponds to that of an object with speed $\hat{\beta}$ in the *geometric* Minkowski-isotopic space, whereas its real cosmological distance is still determined by the standard velocity parameter β in the *physical* Minkowski space. Obviously, the actual value of b is expected to depend, in general, on the quasar considered and represents a measure of the degree of anisotropy and inhomogeneity of the quasar medium. Let us refer to this alternative mechanism of explanation of the large quasar redshift as "Lie-isotopic" (because it is obtained in the context of the Lie-isotopic relativity) or "quasicosmological," since it is able to simulate large redshifts for nearby objects.

Needless to say, our interpretation of large redshifts completely overcomes the problem of the relative superluminal speeds between two components in some quasar nuclei, which clearly do not occur if quasars are nearby objects. Moreover, it does not conflict by any means with the standard expansion of the universe (due to the big bang), because its origin is not of gravitational nature (as stressed before). In other words, in this framework the *local* deformation of the Minkoswki metric in the interior of the quasar atmosphere does not affect the *global* behavior of quasars considered as pointlike objects moving in the curved space-time of Einstein's general relativity. The first problem concerns the (interior) motion of light *inside* the quasar medium;

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Table I

Galaxy Name	z	*Quasar Name*	$\hat{z}$	b
NGC 622	0.018	UBI	0.91	31.91
		BSOI	1.46	20.25
NGC 470	0.009	68	1.88	87.98
		68D	1.53	67.21
NGC 1073	0.004	BSO1	1.94	198.94
		BSO2	0.60	109.98
		RSO	1.40	176.73
NGC 3842	0.020	QSO1	0.34	14.51
		QSO2	0.95	29.75
		QSO3	2.20	41.85
NGC 4319	0.0056	MARK 205	0.07	12.14
NGC 3067	0.0049	3C32	0.5303	82.17

the second one concerns the exterior motion in a vacuum of quasars as pointlike objects subjected to standard gravitation. In different terms our application of Santilli's special relativity to the problem of quasar redshifts can provide a possible revision of the relative speed between the quasar considered and its associated galaxy, while leaving the current theories of the expansion of the galaxy-quasar system totally unaffected.

In order to get some quantitative information on the possible values of b, we consider some cases in which (as stressed by Arp[5]) there are reasonable arguments to think that quasars (sometimes in numbers of two or three together) are associated with a galaxy (the probability of causal association being about is about one in a thousand). A little algebra provides us with the following formula for b as a function of the galaxy and quasar redshifts, z and $\hat{z}$:

$$b = \left[\frac{(z+1)^2+1}{(z+1)^2-1}\right]\left[\frac{(\hat{z}+1)^2-1}{(\hat{z}+1)^2+1}\right]. \qquad (11)$$

The numerical results obtained from Eq. (11) for some of the most probable associations of galaxies and quasars are given in Table I.

Some remarks are in order. First of all, in deriving the values of Table I, we have considered b as a constant for a given quasar, thus neglecting its explicit functional dependence on local quantities and, therefore, its possible variations inside the quasar atmosphere. In this approximation it is clear that the b values represent only an average (and rough) estimate of the deformation of the interior metric. However, also in this approximation, our results are in good qualitative agreement with the main features of the Lie-isotopic Santilli relativity in the following respects. First, the calculated values of b are *different* for *different* quasars (as expected on theoretical grounds). Second, the values of b obtained for the quasars associated with the same galaxy are about of the same order of magnitude. This, too, is a foreseen effect, since on physical grounds the quantity measuring the degree of affinity among quasars is not redshift $\hat{z}$, but the deformation parameter b. Due to the very nature of b, it is expected that, irrespective of $\hat{z}$, quasars associated with the same galaxy have the same physical origin and, therefore, a comparable amount of deformation of the metric. Indeed, if one is of the view that quasars are expelled from the core of the associated galaxy,[5,11] then it is plausible to think that all the quasars expelled from the same galaxy do possess-intrinsic and peculiar non-potential forces acting inside them at about the same rate. Needless to say, the very nature and mechanism giving rise to such nonpotential effects are only a matter of speculation and critically depend on the kind of model adopted for quasars.[1,2]

For instance, in a model that depicts quasars as supermassive stars, magnetoturbulence plays a basic role, and the corresponding magnetic force is just a nonpotential force.[2] On the other hand, in quasars considered as stellar systems their mass is primarily due to stars (including neutron stars) embedded in a hot gas.[12] Although the system as a whole is transparent to light, it is expected that the internal components of such an object are subjected to strong forces of the nonlocal, non-Hamiltonian type.

As a final consideration, let us stress that a generalized Doppler effect of the type (8) [and therefore leading to a different redshift, according to (9)] applies as well to the intergalactic space between quasars and Earth, which is far from empty, and filled instead with dark matter, radiation and particles. This would imply a further (probably second-order) correction to the above redshifts calculations. Moreover, the latter consideration also holds for galaxies (especially for the very distant galaxies), thus leading to a predictable revision of the currently assumed galaxy distances, as already suggested by Santilli.[8] Clearly, in this case one expects values of b for galaxies much lower than for quasars, thus providing only very small corrections to the standard galactic redshifts.

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Résumé

Nous proposons une possible explication des grands déplacements vers le rouge des quasars en termes d'une déformation de leur métrique interne, basée sur la "déformation Lie-isotopique" de la relativité restreinte proposée par Santilli. Cet effet Doppler Lie-isotopique ensuit par la inhomogénéité et anisotropie de l'atmosphère hyperdense des quasars. Nous dérivons. des données astrophysiques disponibles. quelques évaluations numeriques qui montrent une possible révision de la vitesse des quasars relative à la galaxie associée, toutefois en laissant inalterées les opinions actuelles sur l'expansion de l'univers.

Endnotes

1 The reason for introducing the isofield $\hat{\mathcal{R}}$ is to preserve (at an abstract level) linearity in $\hat{\mathcal{M}}$. In fact, transformations in $\hat{\mathcal{M}}$ are now given by

$$x' = A * x = ATx,$$

which are isolinear, that is, linear at the abstract, realization-free level; nevertheless, they are intrinsically nonlinear because of the dependence of T on x [cf. Eq. (3)]. See Refs. 6 to 9.

2 However, we recall that Einstein's general relativity is a special case of Lie-isotopic relativity in the so-called Santili spaces of class III. See Refs. 7 and 8.

3 If the medium is not transparent, the meaning of c is that of the maximal causal speed of propagation inside the medium considered. See Refs. 6 and 8.

4 Metrics of the type (1) have been already used in the literature within different frameworks, all, however, dealing with the problem of a possible breakdown of Lorentz invariance.[10] Clearly, metric (1) is Lorentz noninvariant according to standard views. However, Lorentz symmetry can be proved to be still exact, provided one understands that is is realized at the covering isotopic level. This only apparently paradoxical fact can be seen by noticing that the inhomogeneity and anisotropy of Santilli's metric (1) originate from the physical medium in which motion occurs, whereas the space (empty space) remains perfectly homogeneous and isotropic. The unconvinced reader is strongly referred to Refs 7, 8 for a thorough discussion of this important and delicate point.

References

1. For reviews, see, for example, G.R. Burbidge and M. Burbidge, *Quasi-Stellar Objects* (W.H. Freeman and Co., San Francisco, 1967); M.C. Begelman, R.D. Blandford, and M.J. Rees, Rev. Mod. Phys. **56**, 225 (1984); S.J. Warren and P.C. Hewett, Rep. Prog. Phys. **53**, 1095 (1990).
2. Ya.B. Zeldovich and I.D. Novikov, *Relativistic Astrophysics*, Vol. 1: *Stars and Relativity* (University of Chicago Press, 1971).
3. See, for example, I.I.K. Pualiny-Toth *et al.*, Astron. J. **86**, 371 (1981); E.Recami, Riv. N. Cim. **6** (1986) and references therein.
4. F. Hoyle and G.R. Burbidge, Astrophys. J. **144**, 534 (1966); G.R. Burbidge and M. Burbidge, Astrophys. J. **148**, L107 (1967).
5. H. Arp, Science **174**, 1189 (1971); *Quasar, Redshifts and Controversies* (Interstellar Media, Berkeley, 1987) and references therein.
6. R.M. Santilli: Lett Nuovo Cimento **37**, 545 (1983).
7. *Idem*, Hadronic J. Suppl. **4A**, 155 (1988).
8. *Idem*, *Lie-isotopic Generalization of the Poincaré Symmetry: Classical Formulation*, ICTP preprint IC/91/45 (1991), *Isotopic Generalization of Galilei's and Einstein's Relativities* (Hadronic Press, Tarpon Spring, FL, 1991), Vols. I, II.
9. For exhaustive reviews, see J.V. Kadeisvili, *Santilli's Isotopies of Contemporary Mathematical Structures* (Hadronic Press, FL, 1991); A.K. Aringazin, A. Jannussis, D.F. Lopez, M. Nishioka, B. Veljanoski, *Santilli's Lie-isotopic Generalizations of Galilei's and Einstein's Relativities* (Hadronic Press, FL, 1991); A.K. Aringazin, A. Jannussis, and J.V. Kadeisvili, Uspheki Fiz. Nauk (in press).
10. The literature on Lorentz noninvariance has rapidly grown in the last years. To our aims, see, for example, G.Y. Bogoslowski, Nuovo Cimento

B**40**, 99, 116 (1977); B**43**, 377 (1978); H.B. Nielsen and I. Picek, Nucl. Phys. B**211**, 269 (1983); W.F. Edwards, Am. J. Phys. **31**, 432 (1963); V.N. Strel'tsov, J.I.N.R. Comm. P2-6966 (1973); A.A. Lagunov, *Lectures on Relativity Theory and Gravitation* (Nauka, Moscow, 1987).
11. For a strong experimental support to this hypothesis, see M. Cartili, L. Von Gorkon and R. Stocke, Nature 9 March 1989.
12. See F. Hoyle and W. Fowler, Nature **213**, 373 (1967); S.A. Colgate, Astrophys. J. **150**, 163 (1967).

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