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GAUGE COSMOLOGICAL MODEL WITH VARIABLE LIGHT VELOCITY: III. COMPARISON WITH QSO OBSERVATIONAL DATA

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After a complement to previous papers on the gauge invariance of the Boltzmann collisional operator, we compare a recent homogeneous set of data on radio-QSOs, including angular sizes and bending of lobes, with what is expected from either our new cosmological gauge model or several conventional models. It is shown that the new gauge model provides a much better fit to the angular size distribution versus redshift than the Friedman model with $q_0 = 1/2$, and similarly to the bending, thanks to crude hypotheses on the mechanisms involved with the formation of jets.

1. Introduction

In Refs. 1 and 2, hereafter paper I and paper II, respectively, J. P. Petit has previously developed a cosmological model in which all the so-called constants of physics were made free, so that he had to introduce new physical laws, *gauge laws*, to link conveniently these constants: c (velocity of light), G (gravitation constant), h (Planck's constant), m_e (electron mass), m_P and m_N (proton and neutron masses). It was shown at first that the General Relativity Theory does not require the absolute constancy of G and c separately, but only the absolute constancy of the ratio G/c^2 (Einstein's constant of the field equation). This brought the first linking relation. The other came from geometric considerations: He assumed that the characteristic lengths like Jeans length, Schwarzschild length and Compton length followed the variation of the scale parameter $R(t)$.

Combining these new physical laws gave the following relations:

$$c \propto R^{-1/2} \quad \text{or} \quad Rc^2 = \text{constant} \tag{1}$$

$$m_P \quad \text{and} \quad m_N \propto R \tag{2}$$

$$h \propto R^{3/2} \tag{3}$$

$$G \propto R^{-1} \tag{4}$$

$$V\,(\text{velocity}) \propto R^{-1/2} \tag{5}$$

$$\rho \propto R^{-2}. \tag{6}$$

This new cosmological model, with negative curvature and non-zero pressure, was found to be indifferently filled by photons or matter or a mixture of both, and to obey the single law:

$$R = \sqrt[3]{\frac{9}{4} R_0 c_0^2}\; t^{2/3}. \tag{7}$$

In paper II, the Hubble's law was shown to result from the secular variation of the Planck's constant ($h \propto t$) and not from the expansion process. In this constant energy model, geometrical considerations made some characteristic energies like the ionisation energy to vary like $R(t)$, and this was found to be consistent with additional gauge relations applying to electromagnetism. Then it appeared possible to derive the distances of light sources from the redshift data. They went out as being quite close, for moderate z values, to the classical values derived from the Friedman model with $q_0 = 1/2$, since the ratio:

$$\frac{\text{distance (present model)}}{\text{distance (Friedman model)}} = \frac{(1+z)^2 - 1}{(1+z)^2 + 1} * \left(2 - \frac{2}{\sqrt{1+z}}\right)^{-1} \tag{8}$$

remains close to unity within 5% for $z \leq 2$.

2. A Short Complement about the Gauge Invariance

In paper I, Sec. 5, it was demonstrated that some fundamental equations (Vlasov's, Schrödinger's, Maxwell's) were invariant under the suggested gauge relations. Let us show that the Boltzmann collisional operator is invariant too, writing this equation:

$$\frac{\partial f}{\partial t} + \mathbf{V}\frac{\partial f}{\partial \mathbf{r}} - \frac{\partial \Psi}{\partial \mathbf{r}}\frac{\partial f}{\partial \mathbf{V}} = \int (f' f_1' - f f_1) g\, b\, db\, d\varepsilon\, du\, dv\, dw, \tag{9}$$

where f is the velocity distribution function, g the relative velocity of two particles in an encounter, b a length (impact parameter). Introduce adimensional variables through:

$$\begin{cases} t = t_* \tau; f = f_* \xi; \mathbf{V} = V_* \mathbf{w}; g = V_* \gamma; \mathbf{r} = R_* \zeta \\ \Psi = (G_* m_* / R_*)\psi; b = R_* \beta. \end{cases} \tag{10}$$

The characteristic velocity distribution function is:

$$f_* = n_* \left(\frac{m_*}{2\,\pi\,k\,T}\right)^{3/2} \exp - \left(\frac{m_* V_*^2}{2kT}\right). \tag{11}$$

Following the gauge relations as defined in paper I, $G_* m_*/R_* \propto R_*^{-1}$, $V_* \propto R_*^{-1/2}$, $m_* \propto R_*$ ($m_* V_*^2$ is constant), and the energy kT is constant. To sum up $f \propto R_*^{-3/2}$, whence:

$$\frac{1}{t_*}\frac{\partial\xi}{\partial\tau} + \frac{V_*}{R_*}\mathbf{w}\frac{\partial\xi}{\partial\zeta} - R_*^{-3/2}\frac{\partial\psi}{\partial\zeta}\frac{\partial\xi}{\partial\mathbf{w}} = R_*^{-3/2}\int (\xi'\,\xi'_1 - \xi\,\xi_1)\,\gamma\,\beta\,d\beta\,d\varepsilon\,d_3\mathbf{w}\,. \tag{12}$$

Such a dimensional analysis gives terms varying respectively like t_*^{-1}, $V_*/R_* = R_*^{-3/2}, R_*^{-3/2}$, which implies again:

$$R_* \propto t_*^{2/3} \tag{13}$$

and consequently the invariance of the Boltzmann operator.

3. Observational Tests

After this short parenthesis, let us turn to a comparison of several models with the radio data on 134 QSOs recently published by Barthel and Miley (Ref. 3, hereafter BM), in which they show that distant QSOs have smaller angular sizes, larger bendings and higher luminosities than those nearby. Amongst many observable parameters such as number counts of galaxies or radio-sources, a number of attempts have already been made in the past to compare the distribution of angular sizes versus redshift with a variety of models, because this test has been generally claimed as one of the bests (see, for example, Kapahi, Ref. 4 and La Violette, Ref. 5). Most of the previous conclusions were that the standard Friedman models did not fit at all (with $q_0 = 1/2$) or fitted poorly (with $q_0 = 0$) the data, and that, curiously, only exotic models (such as the "tired-light cosmology", see Refs. 4 and 5) or the classical static model fitted satisfactorily. But all the data used were limited to redshifts $z \leq 1.5$, while the new data compiled by BM reach $z = 2.91$ and therefore we can expect a much higher sensitivity to cosmological and/or evolutionary effects in all their data. Note however that we do not intend to discuss here the given intrinsic powers, since the physical mechanisms involved in the generation of relativistic astrophysical jets are not yet clearly understood.

The situation is apparently simpler concerning the angular size and bending of radio-sources, since geometric properties are mainly concerned *a priori* in both cases, though we cannot ignore that important systematic effects might be at work and the reader is referred to the related comprehensive discussion of BM on the detailed mechanisms involved. In short:

— interactions with the intergalactic medium (IGM) can disrupt very efficiently the initially collimated jets, resulting into the formation of large, turbulent lobes (Ref. 6) of lesser extension: if it is clear that such effects can modify significantly the angular size distribution at a given redshift, more complicated mechanisms have been invoked by BM to explain the stronger bending of lobes observed at large redshifts

— possible evolutionary effects in all the elementary mechanisms implicated above, including gauge processes not yet identified

— observational bias such as the well-known Malmquist's, inducing an underestimate of angular sizes for distant QSOs.

Now, let us suppose in this paper that all such potential effects are not dominant in the data, i.e., the distributions of angular size and bending versus redshift may be considered as good tests for discriminating between different cosmological models and show that the new gauge model provides better fits to these distributions than do the conventional models, except the classical static model which provides again a slightly better fit to the data, despite its physical grounds being no more acceptable.

3.1. *The angular size*

Let subscript 1 refer to the emission epoch and subscript 2 to the reception epoch: since the light emitted by the edges of a source at time t_1 follows radial paths, the angular size ϕ is conserved for a present observer, so that we can write classically, whatever the model

$$\phi = \frac{D(t_1)}{d(t_1)},$$

where $D(t_1)$ is the linear diameter of the source and $d(t_1)$ its metric distance.

In the classical static model, $D(t) = D$ constant, $R(t) = R$ constant, and $d(t_1) = R\,z$ whence

$$\phi = \frac{\phi_0}{z}.$$

In the Friedman model with $q_0 = 1/2$ (the so-called Einstein-de Sitter's), $D(t_1) = D$ constant, $R(t_1) = R(t_2)/(1 + z)$, and $d(t_1) = R(t_1)\,u$ where

$$u = 2\left(1 - \frac{1}{\sqrt{1+z}}\right)$$

and therefore some kind of a paradox arises since the angular size obeys:

$$\phi = \phi_0 \frac{(1+z)^2}{2(1+z-\sqrt{1+z})}.$$

This function is a *minimum* for $z = 1.25$, and then it tends to grow linearly with z.

While in the Friedman model with $q_0 = 0$, $u = z$ whence:

$$\phi = \phi_0 \frac{1+z}{z},$$

where the angular size tends to a constant when z tends to infinity.

Now, with the new gauge model we have $D(t_1) = D(t_2)/(1+z)$, $R(t_1) = R(t_2)/(1+z)$, and $d(t_1) = R(t_1)\,u$ also but with

$$u = \frac{(1+z)^2 - 1}{(1+z)^2 + 1}$$

and the angular size obeys:

$$\phi = \phi_0 \frac{(1+z)^2 + 1}{(1+z)^2 - 1}.$$

When z tends to infinity, ϕ tends to a constant similar to the Friedman model with $q_0 = 0$ but more rapidly. In order to compare quantitatively how these models fit the data, let us write: $\phi = \phi_0 f(z)$ where $f(z)$ is the characteristic function as predicted above by each model. Linear regressions have then been performed between $f(z)$ and the "largest angular size" (LAS after BM) data, either for their complete sample of 134 QSOs, or for various sub-samples according to the morphologies defined by BM. It was found that the one-sided lobe ("D2") sources, cannot be distinguished from the two-sided lobes ("T" and "D1") sources, and so they were included in the final reduced sample of 95 extended objects to which we refer hereafter, thus excluding the steep spectrum core ("SSC") and the complex ("C") sources.

The results of the regressions were as follows, all the given linear coefficients and their rms error bars being in arc second units:

— with the *static model*

$$\phi = (20.0 \pm 2.0)f(z) - (2.6 \pm 19.7)$$

for the complete sample, and

$$\phi = (23.0 \pm 2.0)f(z) + (0.1 \pm 18.8)$$

for the reduced sample.

— with the *Friedman* $q_0 = 0$ *model*

$$\phi = (20.0 \pm 2.0)f(z) - (22.6 \pm 19.7)$$

for the complete sample, and

$$\phi = (23.0 \pm 2.0)f(z) - (22.9 \pm 18.8)$$

for the reduced sample.

— with the *Einstein-de Sitter model*

$$\phi = (28.8 \pm 2.9)f(z) - (89.3 \pm 20.1)$$

for the complete sample, and

$$\phi = (31.4 \pm 3.1)f(z) - (93.2 \pm 20.0)$$

for the reduced sample.

— with the *gauge model*

$$\phi = (21.5 \pm 2.1)f(z) - (19.1 \pm 19.6)$$

for the complete sample, and

$$\phi = (24.5 \pm 2.2)f(z) - (18.6 \pm 18.7)$$

for the reduced sample.

It is clear that the new gauge model provides a fairly better fit to the data than the Einstein-de Sitter's since, whatever the sample, the moderate constant term it implies is marginally significant from a statistical point of view and therefore the (expected) zero value is highly probable. The situation is quite opposite to the conventional model, whatever the sample here, since the constant term there is highly significant from a statistical point of view and its large, negative value is unacceptable on theoretical grounds, unless one supposes that very strong systematic effects such as those suspected above are at work in the data. These results are illustrated in Fig. 1, a plot of the data in which different symbols have been given to extended and compact sources. Because the range in sizes at a given redshift is very large (two orders of magnitude), a logarithmic scale has been used for the ordinates so as to display more clearly some characteristic features of this diagram. The continuous and dotted curves correspond respectively to the gauge and the Einstein-de Sitter model fits, as given above for the reduced sample. The curves corresponding to the static and $q_0 = 1/2$ models have not been drawn for clarity, but in the former case it is pretty close to the gauge model and in the latter case it is intermediate between the two displayed curves at high redshift.

In addition, three sources (belonging to the "T" or "D1" morphologies) of very large angular size have been taken from recent papers (Refs. 7–9), two of them at very low redshifts and a third one at a redshift much higher than the maximum redshift (2.910) in the whole sample of BM: with $z \approx 3.8$, 4C41.17 is the most distant radio-galaxy presently known. Interestingly, the position of this galaxy

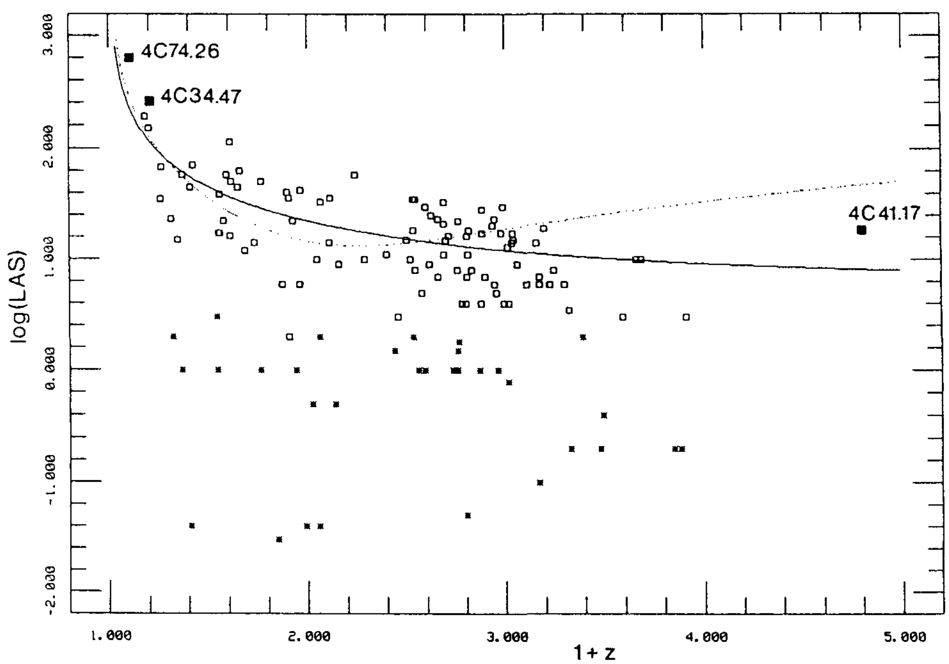

Fig. 1. The largest angular size (LAS, in arcsecond), on a logarithmic scale versus redshift for the 95 extended sources with "T", "D1" and "D2" morphologies (squares) and the 33 compact sources with "SSC" morphology (asterisks). The two curves represent the fits of the gauge model (continuous line) and the Einstein-de Sitter model (dotted line) derived for extended sources in this paper. Three additional radio-sources of very large extent are shown for comparison, 4C41.17 being the farthest galaxy presently known, 4C74.26 the largest radio-source associated with a quasar.

appears in agreement with the impressive upper limit envelope that characterizes triple sources, the shape of which being in fair agreement with the prediction of the gauge model. Also, it is clear that compact sources behave quite differently from triple ones, and moreover they appear to divide into two sub-groups with distinct properties: if the structure of this diagram is not an artefact resulting from the low number of objects involved, then it is tempting to suppose that it could be the signature of markedly different evolutionary trends.

3.2. *The bending*

Let us show also that the more bent, distorted appearance of distant QSOs pointed out by BM may be curiously explained by the new gauge model, provided here again that it is not an artefact resulting from various systematic effects. Since in the new model it is assumed that all the energies are conserved during the cosmic gauge process, we can include the conservation of the rotational energy of the QSO core emitting the jets:

$$E = \frac{1}{2} I \Omega^2 .$$

As $m \propto R$, $I \propto R^3$ and $\Omega \propto R^{-3/2} \Rightarrow \Omega \propto 1/t \propto (1 + z)^{3/2}$, in curious agreement with the one-dimensional power law fit performed by BM on the reduced sample (since the bending is only defined in this latter case) using median values, that is:

$$\log(\text{bending/degrees}) = 0.43 + (1.73 \pm 0.43) \log(1 + z).$$

Now, a linear fit of the gauge law to the same data but with no median values gave:

$$\text{bending (degrees)} = (3.71 \pm 1.24)(1 + z)^{3/2} + (2 \pm 17)$$

in which, again, the constant term is statistically null. Figure 2 is a logarithmic plot of the bending versus redshift in which it can be seen that both laws fit the data and that they cannot be distinguished because of the large natural dispersion.

Now, let us suggest a crude explanation, refering to the recent analysis of Greyber (Ref. 10) on the nature of the central engines in QSOs responsible for their tremendous energy production rates: if we accept the figure, (i) that plasma blobs are ejected at high velocities from the central engine, continuously or not, along the magnetic dipole axis of QSOs and (ii) that this latter is not generally coincident with their angular momentum axis, then we are faced with a model similar to a rotating "garden sprinkler", in which the jets will bend into some kind of a spiral of Archimedes, as long as the interaction with the IGM remains

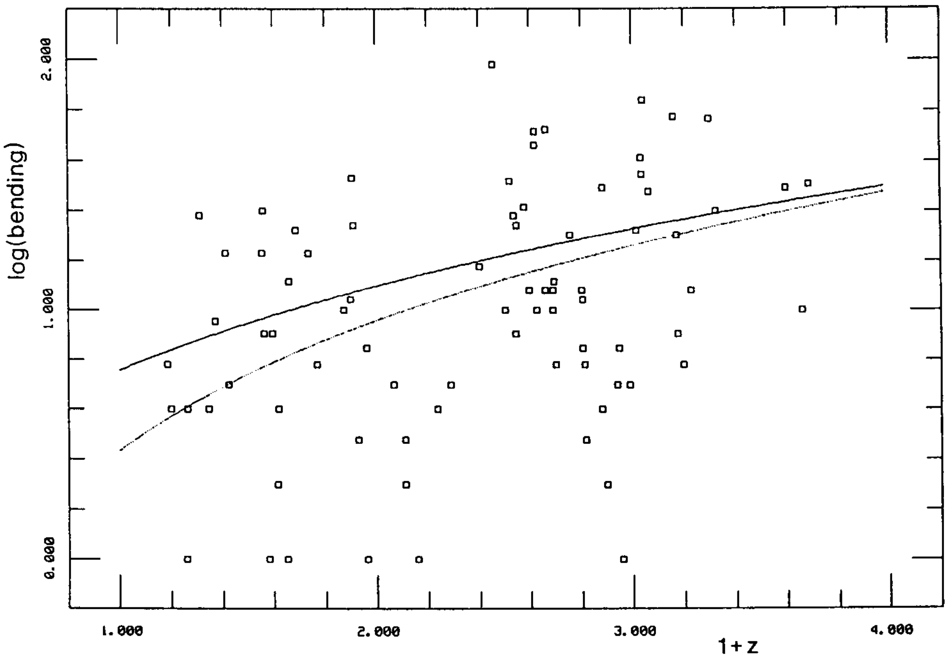

Fig. 2. The bending (in degree), on a logarithmic scale versus redshift for the 83 extended sources with "T" and "D1" morphologies only, for which it is defined. The continuous curve corresponds to the fit of the gauge model, indicating that angular speeds were higher in the past, while the dotted line represents the power law fit of Barthel and Miley (BM).

negligible. And even if this interaction becomes significant at some distance from the nucleus, the jets will stop to expand there, resulting in an increased bending. Since there is no reason why the IGM density would be spherically distributed around QSOs, such interactions could account for the frequently observed asymmetries in their jets together with random effects on the overall bending, as it has been discussed by BM.

As a consequence, the higher the redshift of the QSO, the higher its angular velocity because of the cosmic gauge process, whence the larger the bending of its jets.

4. Conclusion

We have focused on specific features recently evidenced in the distributions of angular sizes and bendings versus redshift for a homogeneous set of 134 radio-QSOs. We found interestingly that the gauge model with "variable constants" provides better or comparable fits to the angular sizes distribution than do the conventional models, and moreover that it provides a direct explanation of the bending distribution while the conventional models fail to do so: because of the cosmic gauge process, quasars and galaxies were rotating more rapidly in the past.

Though it appears unlikely that the observed trends (smaller angular size and larger bending of distant QSOs) will be weakened by future observations over larger samples, we cannot escape the possibilities (i) that these trends are significantly affected by various effects or artefacts such as those recently mentioned by Kapahi (Ref. 11), inducing systematic bias in flux-limited samples of radio-quasars as compared with radio-galaxies, and (ii) that the crude assumptions we made on some of the mechanisms involved with the bending are not representative.

As a conclusion, the gauge model offers a new, attractive alternative to the observed, irritating fact that the geometric properties of extragalactic objects are consistent with non-evolving galaxies in a static Universe, as it has been pointed out for example by La Violette (Ref. 5): further investigations are necessary to test if the new model competes with the tired-light cosmology for number counts of galaxies (Ref. 5), or if it provides a direct explanation to the trend outlined by BM for intrinsic powers, i.e., that the luminosity of distant QSOs is much higher than for those nearby.

References

1. J. P. Petit, *Mod. Phys. Lett.* **A3** (1988) 1527.
2. J. P. Petit, *Mod. Phys. Lett.* **A3** (1988) 1733.
3. P. D. Barthel and G. K. Miley, *Nature* **333** (1988) 319 (BM).
4. V. K. Kapahi, in *Observational Cosmology*, eds. A. Hewitt, G. Burbidge, and L. Z. Fang (Reidel), p. 251.
5. P. A. La Violette, *Ap. J.* **301** (1986) 544.
6. M. L. Norman, J. O. Burns, and M. E. Sulkanen, *Nature* **335** (1988) 146.
7. J. M. Riley, P. J. Warner, S. Rawlings, R. Saunders, and G. G. Pooley, *Mon. Not. R. Astron. Soc.* **236** (1988) 13 p.
8. P. D. Barthel, J. R. Hooimeyer, R. T. Schilizzi, G. K. Miley, and E. Preuss, *Ap. J.* **336** (1989) 601.
9. M. M. Waldrop, *Science* **241** (1988) 905.
10. H. D. Greyber, *Comments Astrophys.* **13** (1989) 201.
11. V. K. Kapahi, *Astron. J.* **97** (1989) 1.