New Study on Quasars and Isotropy of H0

Henri Reboul

1982A&A...108...85R

Astron. Astrophys. 108, 85–88 (1982)

ASTRONOMY AND ASTROPHYSICS

New Study on Quasars and Isotropy of H_0

H. J. Reboul

Laboratoire d'Astronomie, Université des Sciences et Techniques du Languedoc, F-34060 Montpellier, France

Received June 15, accepted December 11, 1981

Summary. A first sample of 132 quasars selected by means of their radio spectral index had lead (Reboul, 1980) to an upper limit to the dipole component of a generalized Hubble modulus HM* and had – a posteriori – revealed that HM* appeared to be at a minimum in the general direction of the Virgo Cluster.

A new and independent sample of 334 quasars has been selected by means of the same criteria. Its study gives two main results:

1. A better limit to any dipole component of HM* which, translated in H_0, is: $H_0(-20\%; +25\%)$.

2. A confirmation of the – now a priori – tested hypothesis: HM* minimum (~ -0.1) in the general direction of the Virgo Cluster at the 0.95 level of confidence.

While (1) seems, for the moment, without cosmological significance, we discuss the possible explanations of (2) and in particular:

an undetected selection bias or systematic errors in the measures,

an extinction by dust (or even gas) through the patchy and expanding world of the numerous superclusters intervening on the line of sight of quasars.

Key words: quasars – cosmology – isotropy – superclusters

Introduction

A first study of the isotropy of H_0 in a sample of 132 quasars (Reboul, 1980, hereafter Paper I) had led to the following conclusions:

(i) At the 0.95 level of confidence, the limits for a possible hemispheric anisotropy of H_0: $(-25\%, +34\%)$.

(ii) The direction of the extremum anisotropy is close to that of the centre of the Local Supercluster (LSC) with the minimum of HM* in the general direction of the centre.

It was suggested, at the end of Paper I, that a new study of this problem on an independent sample could throw some light on the reality of anisotropy and on its cause.

The New Sample

We started with the 1116 measured quasars present in the Veron's catalogue on tape (Veron, 1979).

Corrections

We made a reduction to B magnitudes. The catalogue contained 325 individual measurements of $B-V$. We kept the 280 quasars

Table 1. Mean $B-V$ computed from the Véron catalogue with quasars at $|b| \geqq 30°$ as explained in the text

< z >	< B-V >	< z >	< B-V >	< z >	< B-V >
0.122	0.33 ± 0.09	0.725	0.23 ± 0.04	1.547	0.21 ± 0.05
0.183	0.16 ± 0.07	0.822	0.41 ± 0.04	1.716	0.15 ± 0.08
0.245	0.09 ± 0.05	0.883	0.43 ± 0.06	1.826	0.37 ± 0.12
0.298	0.02 ± 0.05	0.923	0.40 ± 0.06	1.944	0.24 ± 0.08
0.339	0.06 ± 0.05	0.996	0.38 ± 0.07	2.035	0.20 ± 0.05
0.386	0.07 ± 0.07	1.057	0.38 ± 0.11	2.149	0.19 ± 0.04
0.436	0.11 ± 0.05	1.126	0.40 ± 0.05	2.338	0.17 ± 0.05
0.536	0.11 ± 0.03	1.233	0.18 ± 0.05	2.706(8)	0.30 ± 0.06
0.584	0.25 ± 0.07	1.331	0.20 ± 0.06	3.010(1)	0.66
0.649	0.21 ± 0.05	1.423	0.28 ± 0.05	3.530(1)	0.80

Table 2. K_B-correction transcripted from Evans and Hart (1977) or computed as explained in the text. A star marks values computed through their translation formula $K_U \rightarrow K_B$. Two stars show values obtained through an additional extrapolation of K_U

z	K_B	z	K_B	z	K_B	z	K_B
0.	0.00	1.0	- 0.15	2.0	- 0.31	3.0	- 0.05*
0.1	+ 0.02	1.1	- 0.14	2.1	- 0.32	3.1	+ 0.06*
0.2	- 0.11	1.2	- 0.13	2.2	- 0.32	3.2	+ 0.13*
0.3	- 0.15	1.3	- 0.15	2.3	- 0.34	3.3	+ 0.19*
0.4	- 0.19	1.4	- 0.25	2.4	- 0.39	3.4	+ 0.24**
0.5	- 0.28	1.5	- 0.27	2.5	- 0.49	3.5	+ 0.28**
0.6	- 0.30	1.6	- 0.28	2.6	- 0.51*	3.6	+ 0.30**
0.7	- 0.19	1.7	- 0.28	2.7	- 0.46*	3.7	+ 0.32**
0.8	- 0.15	1.8	- 0.28	2.8	- 0.40*	3.8	+ 0.33**
0.9	- 0.17	1.9	- 0.31	2.9	- 0.19*	3.9	+ 0.34**

which had both a $B-V$ measure and $|b| \geqq 30°$. After a sorting by increasing z, a partition by sets of 10 objects gave us a discrete relation between $B-V$ and z which is displayed in Table 1. This standard $B-V$ was then applied to the quasars without direct measure.

The K-korrections were computed, as in Paper I, after Evans and Hardt (1977). The extension of the Evans and Hardt K_B correction beyond $z=2.5$ was made through their transformation formula ($K_U \rightarrow K_B$; number 4 in their paper) for $2.5 < z < 3.4$ and by adding a slight extra-polation of K_U to obtain K_B at $z > 3.4$. Resulting K_B are summarized in Table 2.

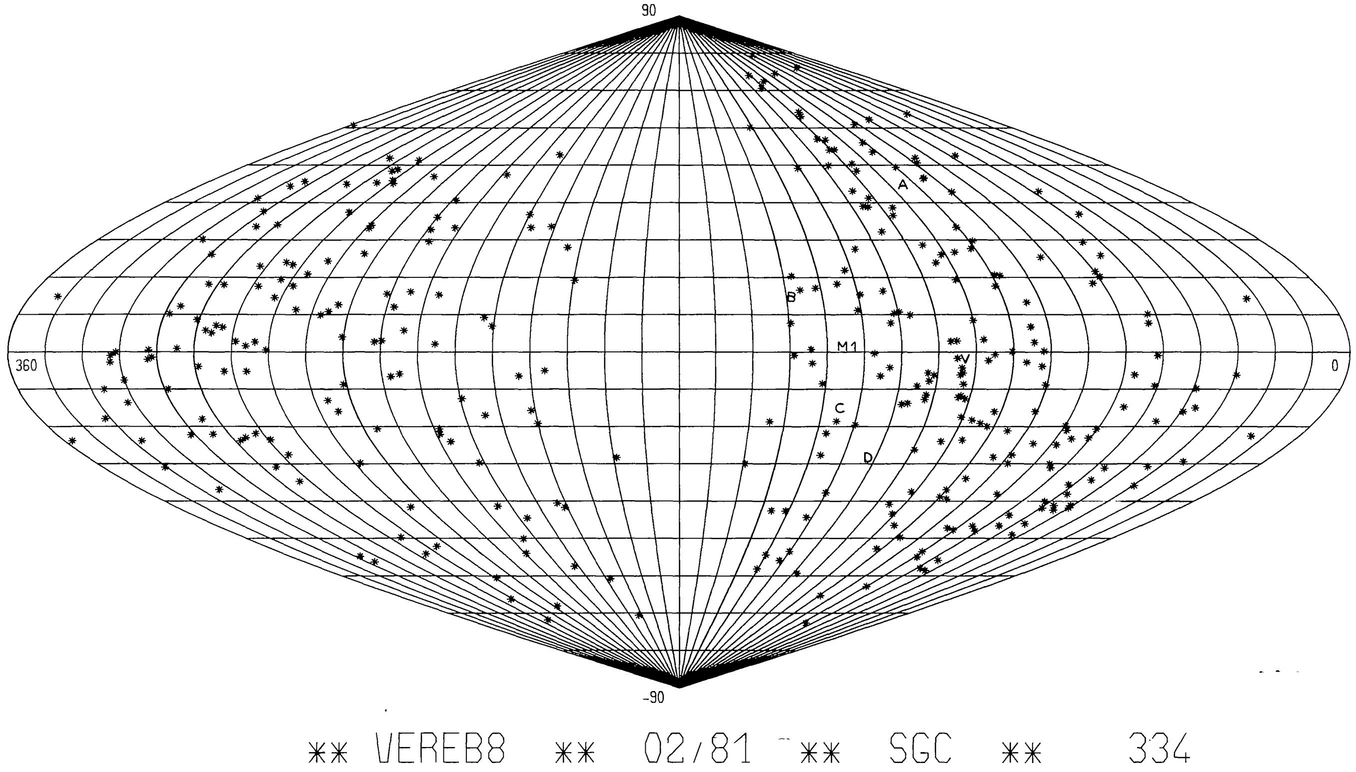

Fig. 1. Selected sample in supergalactic coordinates. Galactic disk is at the periphery and along the central meridian of the chart. Letters show the positions of Virgo Cluster (V), minimum of dipole component of Paper I (M 1) and minima of dipole component (A), 90° (B), 60° (C), and 45° (D) of HM* for the present sample

The correction of galactic extinction was made according to de Vaucouleurs et al. (1976) and lead to B_0 magnitudes.

The generalized Hubble moduli HM* were computed as in Paper I.

Selection

A choice was made among the 1116 candidates on the following criteria:

(i) As in Paper I, a radio spectral index $|\alpha| \leqq 0.3$ or $-\alpha \geqq 0.7$. Note that, in Paper I, α was taken between 408 and 1415 MHz. The Véron catalogue gives only fluxes at 6 and 11 cm (5000 and 2700 MHz), so we have slightly different selection criteria.

(ii) Not to belong to the set of 132 objects of Paper I.

These criteria defined a sample of 334 quasars. It is available on request from the author. Its apparent distribution is shown in Fig. 1 in Supergalactic coordinates. For the whole sample we get ($q_0 = 0.5$):

$\langle \mathrm{HM}^* \rangle = 1.926 \pm 0.016$ (standard error).

Hemispheric Anisotropy

Distribution in Supergalactic Coordinates (SGL, SGB)

In order to test the reality of the effects of Paper I, we intentionally used the same method: steps of 10° in both SGL and SGB for the pole of the partition into hemispheres I (pole) and II.

For all the models (Hoyle $q_0 = -1$ and Friedmann $q_0 = 0$, 0.2, 0.5, 1.0, 1.5, 2.0, 3.0, 5.0), the direction of extremum anisotropy was SGL = 95° and SGB = 45° (point A in Fig. 1).

As in Paper I, we continued our study with the only euclidian $q_0 = 0.5$ Friedmann's model, for which the extremum anisotropy towards the direction above is $\Delta_2(\mathrm{HM}^*) = \langle \mathrm{HM}^* \rangle_I - \langle \mathrm{HM}^* \rangle_{II} = -0.083$ (subscripts 1 or 2 will refer to Paper I or II).

We had, in Paper I, an extremum $\Delta_1(\mathrm{HM}^*) = -0.106$ at SGL = 135° and SGB = 0° (point M1 on Fig. 1) which 57° away from A. The distance of M_1 to the Virgo Cluster (V) was 31°, that of A is 48°.

We find, as in Paper I, a good isotropy between the two supergalactic hemispheres: $\Delta_2(\mathrm{HM}^*) = 0.009$ when the pole of hemisphere I is at SGB = +90°.

Simulations

Twenty simulations were made according to the method described in Paper I: true coordinates, random gaussian HM*. We found an extremum anisotropy higher than that of the real sample in 7 cases out of 20. The a priori hemispheric anisotropy is thus slightly more significant than in Paper I (roughly 2/3 versus 1/2).

But the main goal of this paper is to test a priori the correlation of a minimum of HM* with the proximity of the centre of the LSC – or with the direction of the minimum in Paper I.

Smaller Scale Anisotropy

The scanning of the real sample was done with beams of apertures 90°, 60°, and 45°, by steps of 15° in both supergalactic coordinates.

Table 3. Small scale anisotropy Δ_2' (HM*) $=\langle HM^*\rangle_B - \langle HM^*\rangle_S$ for $q_0=0.5$. Its extrema (+ and −) are displayed for beam apertures ϕ_B from 180° to 45°. SGL and SGB locate the axis of related beams. N_m is the – a priori required – minimum number of objects in a beam (save for $\phi^B=180°$)

ϕ_B	N_m	N N	SGL	SGB	Δ' HM*
180°	(143)	143	255	− 35	+ 0.047
		176	95	+ 45	− 0.039
90°	30	30	210	− 75	+ 0.169
		44	150	+ 15	− 0.115
60°	20	27	270	− 15	+ 0.126
		31	135	− 15	− 0.142
45°	15	16	330	+ 15	+ 0.133
		19	120	− 30	− 0.169

Table 4. Test of the hypothesis "HM* minimum through the Virgo Cluster". ϕ_B is the aperture of the beam centred on the Virgo Cluster. $\langle HM^*\rangle_B$ and σ_B are the mean and standard deviation for the N_B objects in the beam. t is the Student's parameter and P_C the probability for chance to create an effect greater or equal to what is observed

V (SGL = 105° ; SGB = 0°)

ϕ_B	$\langle HM^*\rangle_B$	σ_B	N_B	t	P_c
90°	1.885	0.264	98	1.55	0.062
60°	1.868	0.268	58	1.66	0.050
45°	1.852	0.293	38	1.56	0.063

Table 5. Same as Table 4 but for the direction of M 1

M1 (SGL = 135° ; SGB = 0°)

ϕ_B	$\langle HM^*\rangle_B$	σ_B	N_B	t	P_c
90°	1.849	0.270	68	2.37	0.011
60°	1.814	0.312	31	2.00	0.024
45°	1.792	0.357	24	1.85	0.038

The difference Δ' (HM*) $=\langle HM^*\rangle_B - \langle HM^*\rangle_S$ between the mean HM* in the beam and that of the whole sample was computed for each step.

The positions and values of the extrema of Δ' (HM*) (positive and negative) are displayed in Table 3. Their directions are marked in Fig. 1. The proximity of the minima of HM* to the Virgo Cluster – and even more closely with that of Paper I – is evident.

A very crude analysis taking into account a resolution $\Phi_B/\sqrt{2}$ (Φ_B: angular diameter of the scanning beam) for each scan gives an intersection of the 4 zones of minima at SGL $\sim 125°$, SGB $\sim -20°$ or $\alpha=(11{,}5\pm1)\,h$, $\delta=-(13\pm15)°$.

Discussion

Upper Limit to a Real Anitropy of H_0

The greatest hemispheric anisotropy found among the 20 simulations was $|\Delta\,\mathrm{HM}^*|=0.108$. Since the extremum of the real sample is $|\Delta_2(\mathrm{HM}^*)|=0.083$, we may roughly conclude – with a level of confidence $t>0.95$ – that for any direction:

$|\Delta(\mathrm{HM}^*)|\leq 0.108\pm0.083=0.191$.

This result may be translated in terms of H_0 through the expression of HM* (when assuming isotropy of both absolute magnitude and extragalactic extinction) and leads to an hemispheric limit:

$H_0(\theta,\varphi)=H_0(-20\%,\ +25\%)$; $t>0.95$

a result slightly better than in Paper I, but which seems for the moment to be without cosmological significance: in perturbed FRW models, the isotropy of the 3 K relict radiation implies a dipole component $H_0(\theta,\varphi)$ less than 1% (Dominguez-Tenreiro, 1981).

Correlation with the Geometry of the LSC

The a priori test of the hypotesis "HM* minimum through the general direction of the centre of the LSC" allows the use of the classical tests of confidence.

In the hemisphere centred at the Virgo Cluster (SGL = 105°, SGB = 0°) we have 195 objects with a mean $\langle HM^*\rangle_C=1.903$ ±0.020 (standard error). In the opposite hemisphere 139 objects have an $\langle HM^*\rangle_A=1.959\pm0.026$. The sub-samples C and A differ by $1.75\,\sigma$, which for a one-tail distribution has a probability to occur by chance equal to 4%.

With the pole of partition at the minimum of paper I (point M1 on Fig. 1), the same procedure leads to a probability of 7% ($1.49\,\sigma$).

Going further in the test of the hypothesis we now considere the beams of apertures 90°, 60° and 45° centered at M1 and at the Virgo Cluster. These six investigations were planned a priori and no other has been tried. The results are summarized in Tables 4 and 5.

The level of confidence for the tested hypothesis is higher (>0.93 in the six cases and reaching 0.99 with the 90° beam centered on M 1). The Fig. 2a–d show the distributions of 180°, 90°, 60°, and 45° anisotropies along the supergalactic equator and the correlation with the same data in Paper I.

The hypothesis "HM* minimum through the general direction of the Virgo Cluster" is then confirmed at the 0.95 level of significance.

Extragalactic Extinction

This hypothesis ($\sim0.8\pm0.5$ mag through the centre of the LSC) has been considered as unrealistic in Paper I. Furthermore the new sample does not show a significant relation of HM* versus |SGB|.

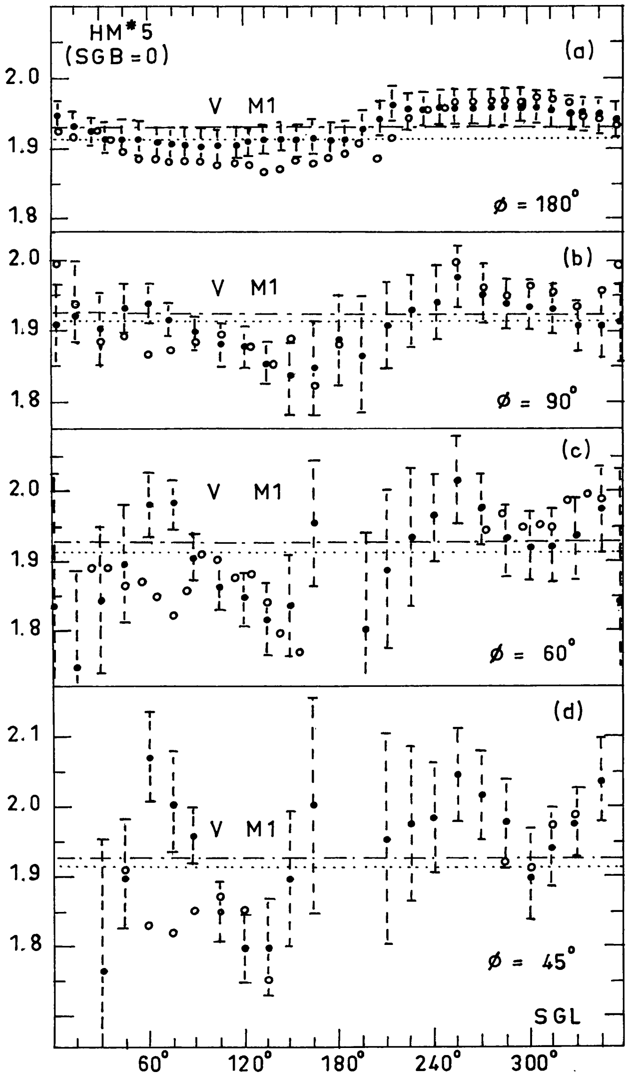

Fig. 2. Anisotropy along the supergalactic equator and its correlation with that of the first sample. The mean HM* in a conical beam whose axis is moved along the supergalactic equator is displayed for beam apertures 180° (a), 90° (b), 60° (c), and 45° (d). The values for the new sample are figured by filled circles and error lines. Those of Paper I are noted by open circles. Horizontal lines show the mean value of the present sample (mixed line) and that of the first sample (dotted line). Note that points do not display independent measures because of the overlap (decreasing from a to d) of the individual beams. V and M1 have the same meaning as in Fig. 1. Pay attention, when comparing with Fig. 1, to the opposite sense of SGL

However, the formulation of the extinction hypothesis was erronous in Paper I. First the LSC does not have the regular structure of a disk. The supergalactic plane is poorly defined in the Southern galactic hemisphere (de Vaucouleurs, 1975; Yahil et al., 1980).

More importantly the partition into superclusters is much broader than that into galaxies. Superclusters are connected to each other by filaments (Joever et al., 1978). Then the light from a quasar has to travel through many superclusters (>20 at $z=1$) and probably through several main condensations before we receive it.

The highest anisotropy in our investigation – and part of it must be accidental – is Δ'(HM*) $= -0.169 \pm 0.064$ at SGL $= 120°$ and SGB $= -30°$ with à 45° beam. Converted into an excess of B-extinction, that is 0.8 magnitude. This value is compatible with a very low extinction by each individual supercluster.

However, this is not a proof of the extinction hypothesis. The question merely is open. There is always the possibility of an undetected selection bias or that of systematic errors in B_0 – and possibly z – as other possible causes of the observed anisotropy.

Conclusion

With the hypotheses of cosmological redshifts of quasars, FRW cosmology as first order approximation and absence of bias, we may give an improved experimental upper limit to a large scale dipole component anisotropy of H_0 as (-20%, $+25\%$).

The slight anisotropy of the generalized Hubble modulus HM* which appeared in Paper I now seems to be confirmed in both its amplitude and direction. HM* is at a minimum (~ -0.1 at 60° resolution) through the general direction of the Virgo Cluster – or perhaps more precisely toward $\alpha \sim 11.5^h$ and $\delta \sim -15°$. The causes of this effect could be:

1. An undetected selection bias or a systematic error on measurements. Probability: high (author's opinion).
2. Chance. Probability $<5\%$.
3. Extragalactic extinction in superclusters.
4. Real H_0 anisotropy.
5. Anisotropy of the luminosity of quasars.

Acknowledgements. My thanks are going to P. and M. P. Véron who provided me with a copy of their catalogue of quasars on tape and who made me aware of many related informations. I am much indebted to the referee G. de Vaucouleurs who meticulously corrected the successive versions of this paper.

References

de Vaucouleurs, G., 1975, *Astrophys. J.* **202**, 610
de Vaucouleurs, G., de Vaucouleurs, A., Corwin, H.G., Jr.: 1976, in *Second Reference Catalogue of Bright Galaxies*, University of Texas Press
Dominguez-Tenreiro, R.: 1981, *Astron. Astrophys.* **93**, 306
Evans, A., Hart, D.: 1977, *Astron. Astrophys.* **58**, 241
Joever, M., Einasto, J., Tago, E.: 1978, *Monthly Notices Roy. Astron. Soc.* **185**, 357
Reboul, H.J.: 1980, *Astron. Astrophys.* **89**, 272
Véron, P., Véron, M.P.: 1980 (private communication)
White, S.D.M., Silk, J.: 1979, *Astrophys. J.* **231**, 1
Yahil, A., Sandage, A., Tammann, G.A.: 1980, *Astrophys. J.* **242**, 448