Astron. Astrophys. 108, 256–264 (1982)

ASTRONOMY AND ASTROPHYSICS

A Possible Large-scale Anisotropy of the Universe

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Received March 31, accepted November 5, 1981

Summary. The three-dimensional distribution of quasars known to date shows a singular zone, almost planar, about 200 Mpc wide, 3000 Mpc away, covering half the sky.

A general stratification of the universe, parallel to this zone, is possible; this stratification seems to show up in the distribution and the kinematics of nearby galaxies (at least up to 30 Mpc).

From this facts we get a Friedmann-Lemaitre model

$q_0 = -1.1, \quad \Omega_0 = 0.1$

together with a general anisotropy around the direction

(5 h 46 m, $+6°50'$).

Key words: cosmology – quasi-stellar objects – galaxies – intergalactic matter – background radiation

I. A Singular Zone

1. Detection

Certain cosmogonical considerations (bipartition matter-antimatter) suggest that there may exist in the universe a singular planar zone, where the process of condensation into galaxies has not taken place (Fliche and Souriau, 1979; Souriau, 1980). Such a region could be detected by absorption lines in the spectra of objects situated behind it.

Absorption lines observed in the spectra of quasars (Q.S.O.) are generally narrow. There are, however, several quasars with *broad absorption lines*. Assuming that these lines could be a manifestation of intervening gaseous clouds, and applying naively Hubble's law, we can locate them in space. Among the possible hydrogen clouds so detected (Lyman α lines observed in absorption), there are four:

α: (1246 − 057)	$z_{abs} = 2.05$ [a–c]
β: (1331 + 170)	$z_{abs} = 1.78$ [d–f]
γ: (1334 + 285), or RS23	$z_{abs} = 1.87$ [g]
δ: (2225 − 055), or PHL 5200	$z_{abs} = 1.88$ [h, i]

a Osmer and Smith (1977)
b Boksenberg et al. (1978)
c Boksenberg (1978)
d Baldwin et al. (1973)
e Wolfe et al. (1979)

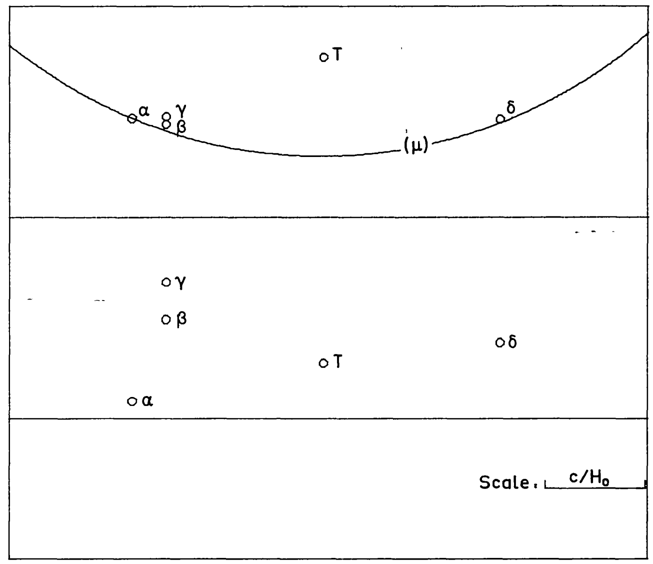

Fig. 1

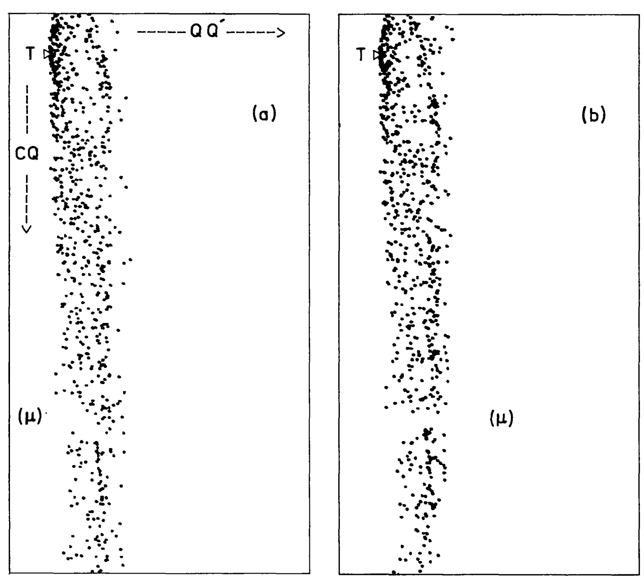

Fig. 2a and b

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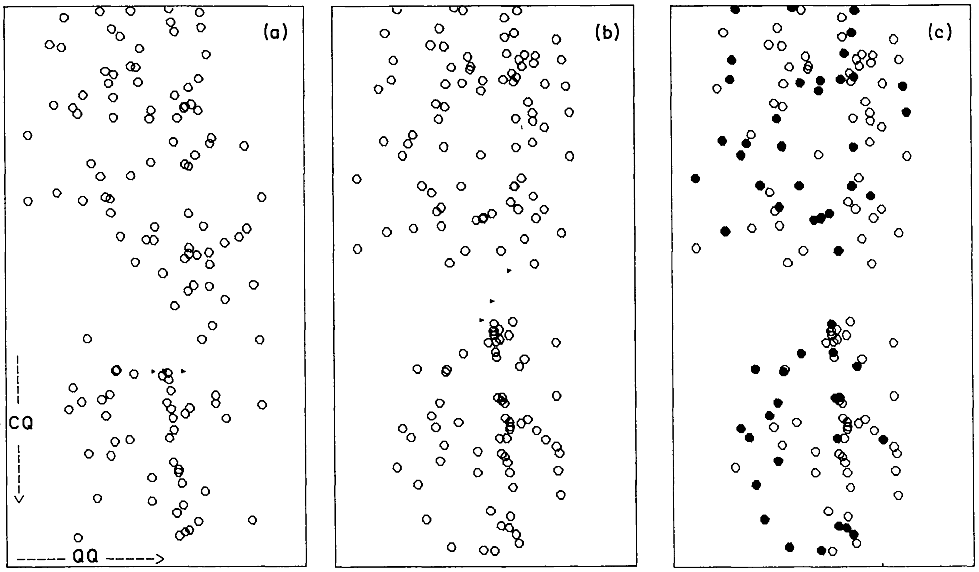

Fig. 3a–c

f Carswell et al. (1975)
g Burbidge (1970)
h Lynds (1967)
i Burbidge (1980)

which have the remarkable property of being *almost coplanar*. More precisely, the sphere (μ) going through α, β, γ, δ has a very large radius (# $5c/H_0$). We are inside (μ) (Fig. 1), at a distance of (μ) of 0.97 c/H_0.

The direction of the center C of (μ) is

(ω_0) (5 h 45m, $+6°40'$)

or, in radians

(ω_0) (1.504, $+0.115$);

this direction is in the constellation Orion at two degrees from Betelgeuse.

Let us study the distribution of quasars in the neighborhood of this geometrical sphere: we shall make a diagram by plotting, for each quasar Q, and for the Earth T, the distance QQ' as abscissa (Q' = projection of Q on CT), and $-CQ$ as ordinate. *We see clearly an empty band* (Fig. 2a), containing the four clouds, denoted by Δ (Fig. 3a); if this fact is significant (see Sect. I.3), it shows a singular region (μ) of the universe where matter appears not in condensed form (quasars) but rather in diffuse form (hydrogen clouds). The thickness of this zone is not negligible on a cosmological scale (# 200 Mpc); this is sufficient to explain by multiple absorptions, the widths of the observed lines.

2. *Interpretation in a Universe of Friedmann-Lemaitre*

We notice on Figs. 2a and 3a that the band (μ) is not horizontal as it should be if it were a spherical zone, but shows a pronounced slope and curvature. It is hard to interpret this in the context of the naive Hubble model: this zone would have the shape of a non-spherical surface of revolution, with axis going through the Earth; however this difficulty will disappear when we use a more precise cosmological model.

The relativistic models compatible with the properties of the 3 K background radiation are the models of Friedmann-Lemaitre; they depend on two dimensionless parameters; the density parameters Ω_0 and the deceleration parameters q_0; one can also use the reduced cosmological constant

$$\lambda_0 = \frac{\Omega_0}{2} - q_0$$

and the reduced curvature

$$k_0 = \tfrac{3}{2}\Omega_0 - q_0 - 1.$$

If $k_0 = 0$, the geometry of space is non-euclidean; a non-euclidean plane seems curved to a distant observer using Hubble's law; curving away from the observer if $k_0 < 0$, towards him if $k_0 > 0$.

It may be that it is this effect that produces the approximatively spherical appearance of (μ) in Hubble's model; we can thus assume that the singular region is (physically) a plane, if the curvature k of space is positive. In this case the geometry of space is that of a hypersphere S_3, the zone (μ) being an equatorial band.

Indeed, this hypothesis gives better results than the preceding one (a spherical zone in a flat universe); after relativistic corrections, Figs. 2a and 3a are replaced by Figs. 2b and 3b, in which there is no more any significant distorsion.

Figure 4 is obtained by a mapping that is particularly adapted to the case of a universe that is spatially a sphere S_3; one embeds S_3 into a numerical space $\mathbb{R}^4$, and one projects orthogonally on a diametral 2-plane (in this case, on the plane orthogonal to (μ) and going through the Earth T). The scale of this global chart of the universe notwithstanding, we clearly see (μ) in diametral position.

An optimization method (see Sect. I.3), allows us to determine the parameters leading to this result:

Cosmological parameters:

$q_0 = -1.12 \pm 0.01$;

Ω_0: between 0.05 and 0.20

(larger values of the density parameter are allowed, but are less satisfactory).

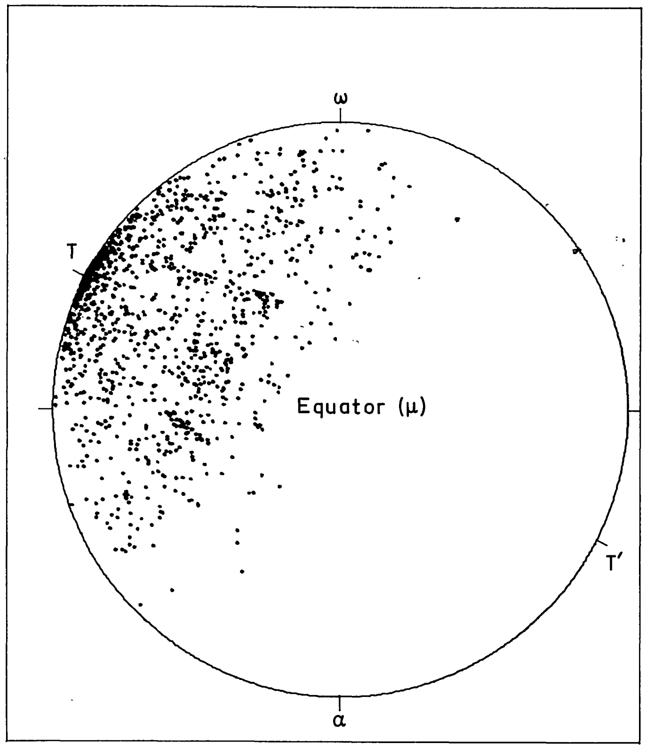

Fig. 4

Equatorial coordinates of the axis perpendicular to (μ), in opposite direction (radians):

(ω) $(1.51 \pm 0.01, \quad +0.12 \pm 0.01)$

(i.e. the values given in the abstract). Distance from the Earth to (μ): $(0.91 \pm 0.01)\, c/H_0$

Table 1. Situation of the zone (μ) in the sky: redshifts versus angular distance d to α: (17 h 46 mn 20 s. $-6°55'$) (1950)

d (deg)		z_{min}		z_{max}
0	(from	0.852	to	0.896)
5	(from	0.855	to	0.899)
10	(from	0.863	to	0.908)
15	(from	0.877	to	0.922)
20	(from	0.898	to	0.944)
25	(from	0.925	to	0.972)
30	(from	0.959	to	1.008)
35	(from	1.003	to	1.054)
40	(from	1.057	to	1.111)
45	(from	1.124	to	1.181)
50	(from	1.206	to	1.268)
55	(from	1.308	to	1.375)
60	(from	1.436	to	1.510)
65	(from	1.596	to	1.680)
70	(from	1.801	to	1.897)
75	(from	2.066	to	2.181)
80	(from	2.415	to	2.556)
85	(from	2.880	to	3.059)
90	(from	3.498	to	3.732)

Figures 2b, 3b, and 4, and Table 1 have been drawn using these values, with an average choice

$\Omega_0 = 0.10$

of the density parameter.

We have so determined the position of (μ) starting with two distinct hypotheses, based on independent observations:

(i) (μ) contains the clouds α, β, γ, δ determined by absorption lines.

(ii) (μ) is an empty zone in the distribution of all quasars.

Notice the convergence of the procedures: to the given precision, the directions (ω_0) and (ω) coincide; the four clouds are situated in the interior of (μ) (Fig. 3b).

Let us now study the cosmological model just determined: it is a universe with a big-bang, with eternal expansion (which is compatible with positive spatial curvature because of a positive cosmological constant). It turns out that it agrees with the various available cosmological tests:

A. The value of Ω_0 is not only positive, it is within the range of various estimations given by the dynamics of galaxies: $\Omega_0 = 0.06 \pm 0.03$ (Gunn and Tinsley, 1975); $\Omega_0 = 0.4 \pm 0.2$ (Peebles, 1979).

The *redshift-luminosity* relation for such a universe it quite satisfactory.

B. For the *galaxies* (Gunn and Tinsley, 1975);

C. For *Quasars* (Fliche and Souriau, 1979; Fliche, 1981; Thesis).

D. The *redshift-angular diameter* relationship for *radio sources* is at least equally good for this model as for the models without cosmological constant (Fliche and Souriau, 1979; Fliche, 1981).

E. The *age of the universe*, which is 16 billion yr in this model (assuming the high value $H_0 = 100$ km/s/Mpc), is compatible with the estimated ages of stars and globular clusters (14–16 billion yr; cf. Tammann, 1979).

F. An interesting property of this model is to *eliminate the paradox of the isotropy of background radiation* (in the standard model with negative curvature, the sources of radiation in different directions are causally independent). Here finiteness of space together with a focalization effect (for $z \# 500$) shows that the sources of 3 K radiation are physically close together; it is not necessary to postulate arbitrarily a strict initial symmetry to explain the data. Present-day symmetry can thus be explained as a simple evolutionary effect, due to the expansion, starting with any anisotropic initial structure.

3. *Discussion*

It remains to be seen whether the structure displayed here may be an artefact or due to a bias. We shall now discuss the various possibilities.

A. Data

It is clear that the precision of redshift measurements plays a crucial role in this work: the result can be compromised by a single erroneous object.

Consequently we have built a critical catalog of all Q.S.O. published to date (Triay, 1981b). From this catalog, we have taken the sample of 1146 objects containing *all* redshifts given as certain by their authors after a measure of an individual spectrum. The redshifts obtained only by the objective prism (or grism) method are not sufficiently reliable or precise to be exploited [see (E)].

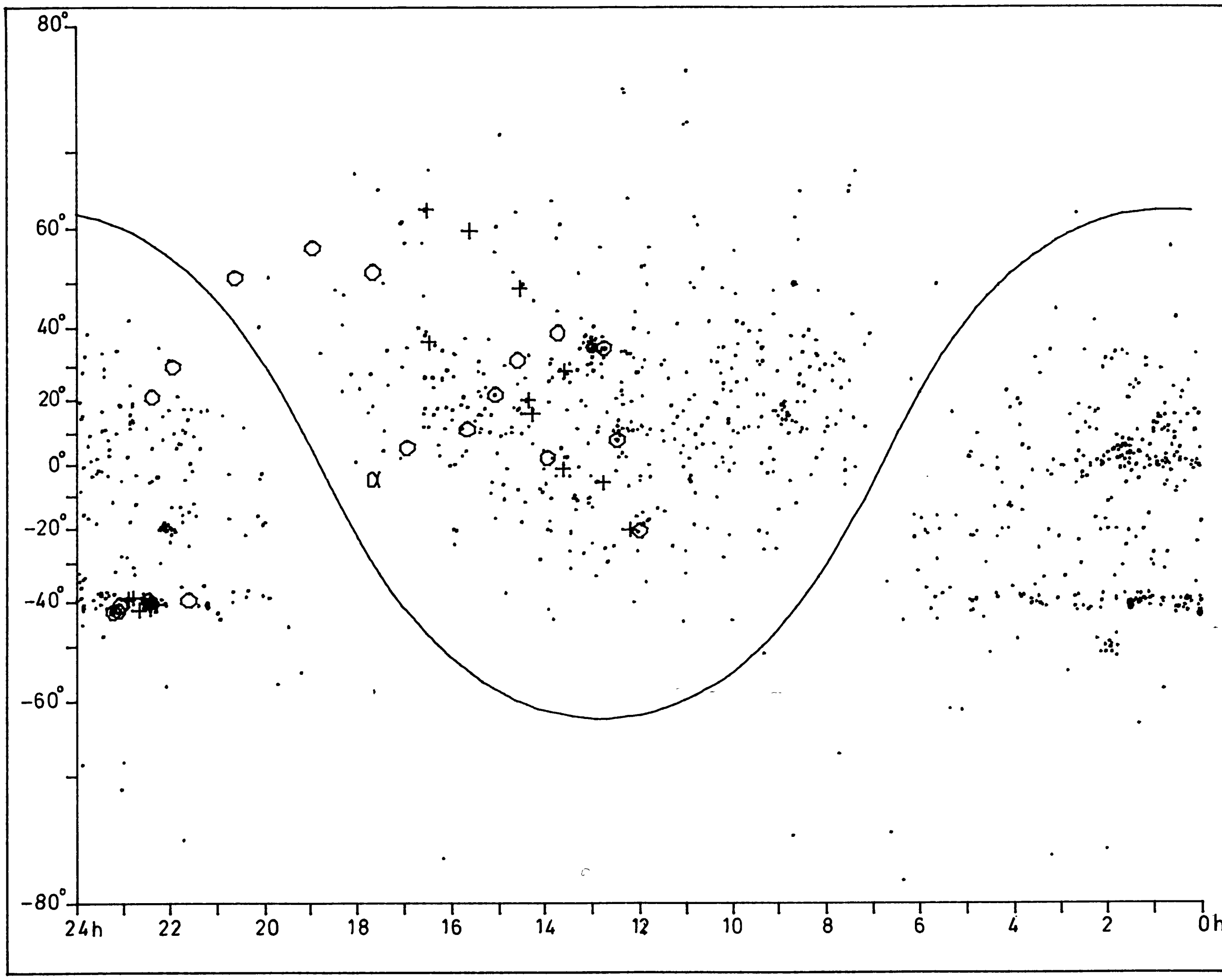

Fig. 5

B. Precision of Data

The high-resolution spectra obtained after several hours of exposure on a large instrument, allow determination of redshifts with a precision better than 0.001, but most data (low resolution spectra) have a precision of 0.01. The band to be observed has a width Δz that varies from 0.05 to 0.20, depending of the direction of observation; the mean error of redshifts does not affect significantly our analysis. Besides one notices, that if one introduces artificially a gaussian error of the order of 0.01 in the redshifts the empty band persists, even though it becomes less wide.

C. Selection Effects in Observation

The empty band (μ) is particularly clear in Figs. 2b and 3b; the neighbouring bands of the same width contain respectively 19 and 18 objects. Figure 5 is a Mercator view of the sky, with the galactic plane marked. Quasars of our sample are denoted by points, except for the 19+18 objects bordering (μ) (○: in front, + back of (μ)]. The objects denoted by ○ or + are uniformly distributed over a half of the sky, around the center denoted by α (in Ophiuchus). There is no obvious selection effect by direction.

Another analysis of these effects can be done on Fig. 4. On this diagram, the objects of equal redshift are situated on a chord perpendicular to the diameter TT' (where T is the Earth); on the other hand, the points situated in a given direction of the sky are situated on a half-ellipse with axis TT'. We see that the zone (μ) is transversal both to the chords and the ellipses, which shows that the appearance of (μ) is due neither to a redshift selection effect nor to a selection by sighting direction nor to a – highly improbable – correlation of these two effects.

Elliptical trails visible on this figure correspond to systematic searches in various regions of the sky. One of them is particularly interesting: it is the search of Hoag et al. in the neighbourhood of (23 h, −40°) (see also Fig. 5). In Fig. 6, the objects of the window

$$(\{22\text{ h }45\text{ m}\pm 45\text{ m}\},\quad \{-40°\pm 5°\})$$

have been distinguished. The objects that are close to each other are close in space: consequently the visible gap at the intersection with the band (μ) is the direct expression of an observation. We see that an exhaustive sampling of a small region (1/250 of the sky) is sufficient to display (μ).

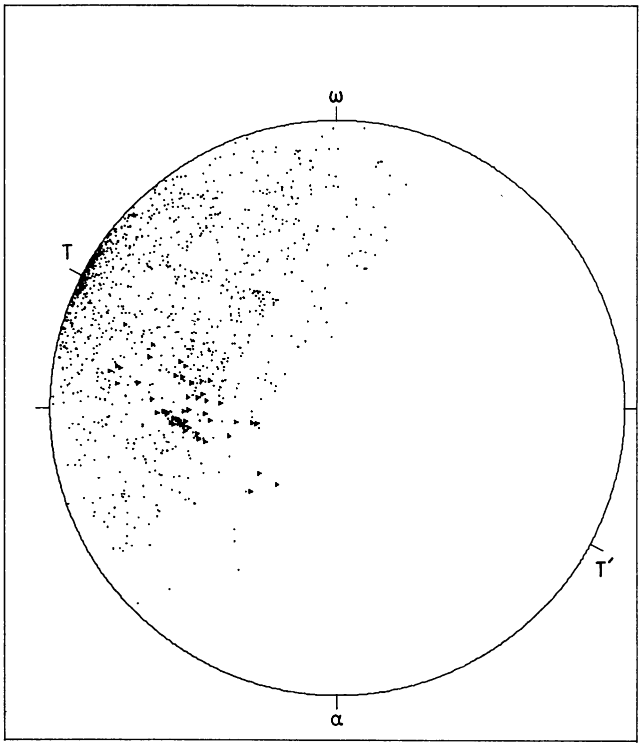

Fig. 6

Table 2. Redshifts needing more precision

Position (1950)	Redshift	Ref.
(12 h 13 m 16 s 00, − 0°17′53″0)	2.73	[1]
(12 h 58 m 45 s 20, + 1°37′45″0)	2.00	[1]
(13 h 42 m 8 s 90, + 2°53′ 9″0)	1.51	[1]
(21 h 20 m 35 s 22, −70°10′53″1)	1.98	[2]
(22 h 00 m 14 s 80, −18°14′30″0)	1.59	[3]
(22 h 11 m 23 s 80, −19°39′24″0)	1.68	[3]
(22 h 14 m 6 s 40, −20°48′ 1″0)	1.675	[3]

1: Mac Alpine and Williams (1981)
2: Savage and Wright (1981)
3: Savage and Bolton (1979)

D. Optimization and Significance Tests

In order to determine the best parameters compatible with the interpretation of (μ), we maximize either the width of the empty band, or the number of objects in adjacent bands of same width, or else a combination of the two above variables, always with comparable results.

These optimizations allowed us to determine 4 parameters (the direction and distance of the empty zone and the deceleration parameter) and estimate the density parameter (see results above).

In order to verify whether this result is significant we have used various methods, in particular a random search for empty bands analogous to (μ); however, the broadest bands discovered by this method are due to selection effects; consequently it is hard to draw from them any conclusion about the significance level of (μ).

The most precise results were obtained by the following procedure: Our sample was divided at random in two equal parts, one of which was used for optimization of parameters and the other as a significance test: if the observed zone was an random effect, the two samples would be independant. Consequently, the probability of observing an empty band in the second sample would be given by the law of Poisson, i.e. by e^{-n}, where n is the mean number of objects in zones of the same width. The average value of n, obtained from several random partitions, is equal to 8.8, giving a probability < 0.00015 that the appearance of the zone (μ) is due to chance.

These and other statistical tests are studied in details in Triay (1981a; Thesis).

E. Predictions

We have indicated the existence and direction of the zone (μ) in 1979 (Fliche and Souriau, 1979; Souriau, 1980), starting with 627 objects in the catalog by Burbidge et al. (1977).

In the last two years we have collected all new publications on quasars; in March 1980, we had 811 confirmed objects; in a publication written at this time (manuscript submitted to Astron. Astrophys.: Fliche et al., 1980), we have indicated a list of quasars that seemed situated in the zone (μ) by their redshifts estimated through an objective prism; we proposed them as a crucial test. Since that time, the individual spectra of these objects have been published; they are contained in the above sample of specially studied objects [see (C)]; consequently, the proposed test has been answered positively.

We give here (Table 2) a new list of objects which, by preliminary determinations (objective prism or grism), are situated in the zone (μ) or in its neighbourhood. They constitute new tests that can be answered by more precise observations.

Since our first publication, the number of usable objects has increased by 85%, and 150% in the neighbourhood of (μ); the optimized width of the empty band has diminished by about one third, and the statistical significance has remained practically unchanged [the objects from the first sample by Burbidge et al. (1977) are distinguished by black dots on the Fig. 3c]. This is what one expects of a real phenomenon about which increasing information is gathered through new observations. If, on the other hand, the empty zone were due to chance, the probability of its being respected by the new data would be very small.

II. General Anisotropy and Nearby Galaxies

1. Anisotropy and Stratification

The Friedmann-Lemaitre models describe a homogeneous and isotropic universe. This fact is translated mathematically into the existence of a 6-parameter isometry group for these models; in the case of positive curvature, this group is SO(4), group of rotations of the hypersphere S_3.

If the existence of the zone (μ) is confirmed, it will break the symmetry of the universe – and reduce it to the rotations of S_3 that transform (μ) into itself; they define the group SO(3) of rotations around the two poles α and ω of (μ) (see Fig. 4).

No matter what the cosmogonical origine of (μ), this zone can be considered as a manifestation of a general anisotropy defined by this group SO(3). It is natural to ask whether other manifestations of this anisotropy are observable. Concerning the distribution of quasars one can look for density fluctuations along surfaces

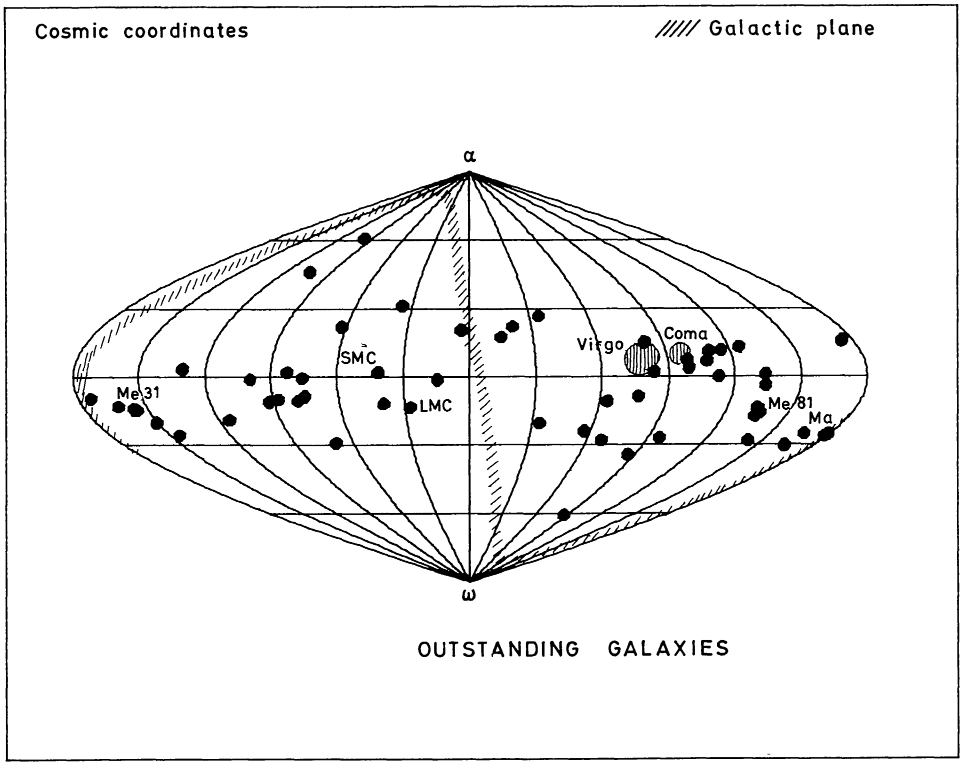

Fig. 7

parallel to (μ), which are "orbits" of SO(3) in group-theoretical terminology: consequently, the universe could be *stratified* parallel to (μ).

A first study seems to indicate that empty bands parallel to (μ) do exist (Souriau, 1980); since celestial mechanics prevents them from beeing truly empty (Fliche, 1981, Thesis), they should also contain clouds, responsible for a part of the absorption lines observed in the spectra of quasars.

In particular, it turns out that certain systems of *broad* absorption lines namely

ε_1 : (2240 − 370), $z_{abs} = 1.80$ [m]

ε_2 : idem, $z_{abs} = 1.70$ [m]

ζ: (2238 − 412), $z_{abs} = 1.70$ [m]

η_1 : (1157 + 0.14), $z_{abs} = 1.9436$ [n, o]

η_2 : idem, $z_{abs} = 1.9686$ [n]

η_3 : idem, $z_{abs} = 1.98$ [n]

m Clowes et al. (1979)
n Wright et al. (1979)
o Wolfe and Briggs (1981)

are situated in relatively broad empty zones; however, the mean error on the measurements of redshifts of Q.S.O. does not allow us to assert their existence with certainty; nevertheless, if their existence were confirmed, one could envisage the following interpretation:

The three absorption systems of object η indicate three clouds in one and the same zone devoid of quasars;

The absorption systems ε_2 and ζ indicate one and the same cloud (or one and the same stratum), interposed between the Earth and these two quasars that are at a distance of 4° from each other.

On the other hand, the multiple Lyman α absorption lines observed in the spectra of distant objects have very peculiar characteristics and distribution (Sargent et al., 1980), which could be due to a *fine level of stratification* (< 25 Mpc).

This possible anisotropy would also have *kinematical* aspects. Indeed, the object bordering (μ) have redshifts between 0.9 and 2.7, and are consequently observed at very different dates of the past. The zone (μ), as well as a possible stratification, are observed only if they are permanent, and consequently primeval. If these structures have global velocities, they must be parallel to the stratification plane: transversal velocities of a few thousands of km/s would be sufficient to destroy them.

It is clear that this kinematical study of quasars is presently as difficult as the study of their stratification; we shall consequently ask whether the general anisotropy is observable in less distant regions.

2. *Distribution of Nearby Galaxies*

A. Outstanding Galaxies

de Vaucouleurs (1981) has pointed out to us that the galaxies of the Local Group and, more generally the "Local Cloud", are distributed on a flat disk, the direction of which is very close to the stratification plane defined above.

One can verify this by constructing a map of the sky in "cosmic coordinates" CL, CB (such that the pole CB = 90° coincides with the axis of anisotropy the direction of which is given by (ω)]. In Fig. 7, obtained in this way, we have given the positions of the "outstanding galaxies", defined in de Vaucouleurs, 1975, with distances less than 10 Mpc. We notice that *these galaxies are almost*

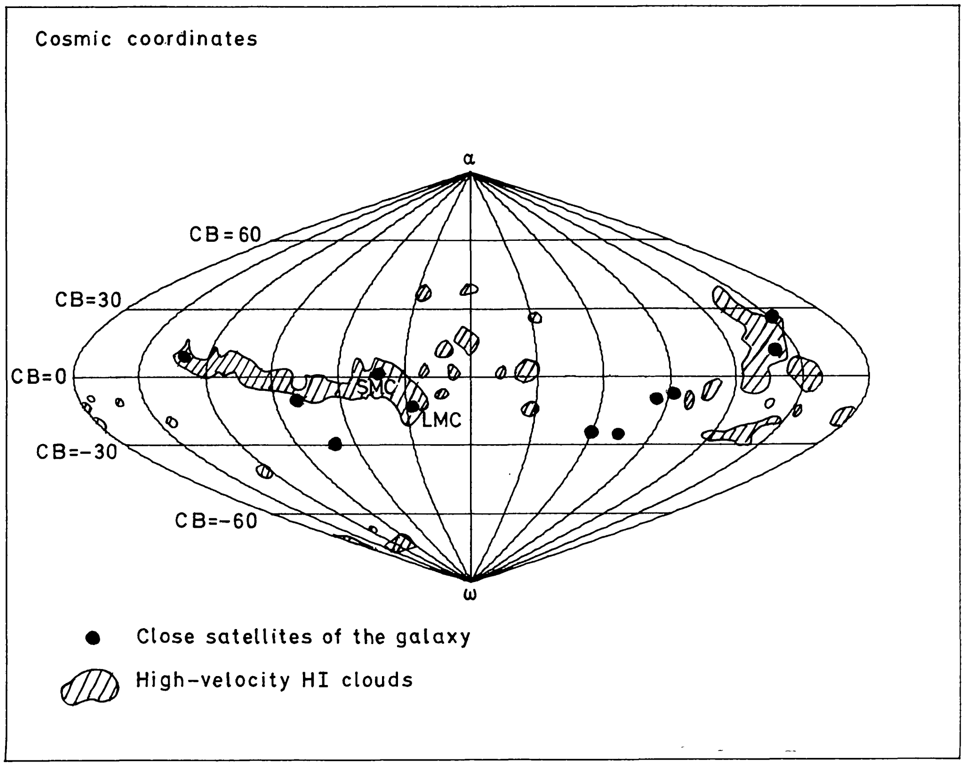

Fig. 8

confined to the band $-30° < \mathrm{CB} < 30°$, which contains only half of the sky surface.

Moreover, the principal nearby clusters, Virgo and Coma, are also in this zone (same figure).

B. Close Satellites of the Galaxy

Even though the plane of our Galaxy makes an angle of 80° with the direction of stratification, the system constituted of the Galaxy and its satellites (LMc, SMc, Scl, For, Leo I and II, Sex, C, UMa, UMi, Dra, and Peg) is *strongly flattened* in the direction of the general stratification, as one can see on Fig. 8. On the other hand, M31 and its major satellites (NGC 147, 185, 205, 221) display an analogous arrangement.

C. High Velocity H I Clouds

There is another possibly extragalactic structure that has the same sky distribution, the H I clouds that are observed, in particular, near the Magellanic clouds ("Magellanic Stream"). We have represented it on the same Fig. 8 (from de Vaucouleurs et al., 1975). No matter what the true nature and the distance of these objects, *we notice that these clouds are also preferentially situated in the same zone* $= -30° < \mathrm{CB} < 30°$.

3. *Kinematical Anisotropy*

If the suspected stratification is permanent, the relative velocities of the components of a given region have to be parallel to this stratification. We so forecast a planar kinematics, orthogonal to the direction (ω) (see Sect. II.1)

A certain number of velocities of this kind have been measured, allowing a verification of this hypothesis. Figure 9 is borrowed from de Vaucouleurs et al. (1981); we find in it the apex of the Sun with respect to: the background radiation denoted by (S/*), the Local Group of galaxies: (S/L), and to a sample of 300 galaxies chosen in the distance 3–32 Mpc: (S/G). The first position is an average of several published measurements (Smoot et al., 1977; Corey, 1978; Gorenstein, 1978; Cheng et al., 1979; Cheng et al., 1980). The other two follow from a new study that uses the radio-astronomical Tully-Fischer method.

We notice that these points are located, within the precision of the measurements, on the line perpendicular to the direction of (ω) (CB $=0$); similarly of course for the relative apexes: Local Group/galaxies: (L/G), Local Group/3 K: (L/*), galaxies/3 K: (G/*).

It is the last three apexes that are most significant, since they are obtained by elimination of the proper motion of the Sun with respect to the Galaxy. The direction of their plane differs by only 2° from the direction perpendicular to (ω); within the given precision, the two directions coincide.

Thus, these observations tend to confirm the hypothesis: *the general kinematics of objects between* 0 *and* 30 Mpc *seems planar, and exactly in the directions perpendicular to* (ω).

Conclusions

Quite diverse observations (quasars, galaxies, blackbody radiation) made in most regions of the sky have confirmed the cosmological structure that we proposed (Fliche and Souriau, 1980; Souriau, 1980); this model would have been eliminated if a few observations had given different results. If the conclusions of Sects. I and II above are confirmed, they indicate that matter is stratified, geometrically and kinematically, in most of the

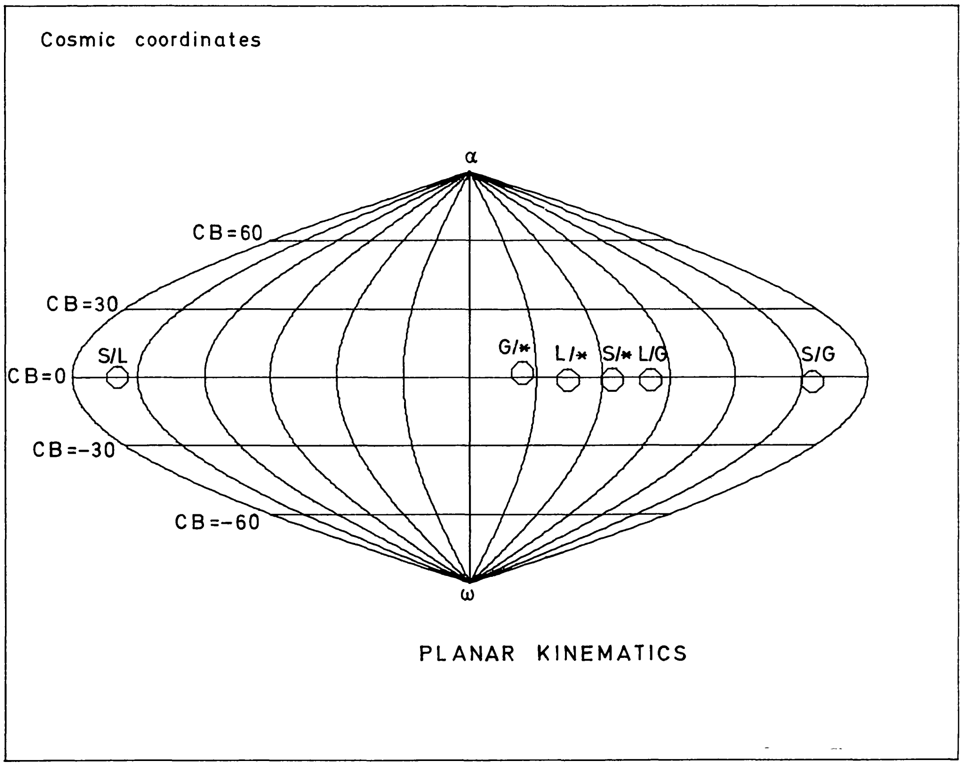

Fig. 9

Universe; otherwise we would be forced to assume that we live in an exceptional region.

The easiest additional verifications involve the distribution of quasars in the neighbourhood of the zone (μ). An exhaustive search for all quasars in a limited region of the sky (e.g. $5° \times 5°$) in a given zone of redshifts has already been performed (by Osmer et al.). The region of Pegasus (22 h 30 m, +15°) or that of Virgo (13 h, 0°) correspond to relevant redshifts centered around $z=2$ (see Table 1), which are particularly easy to observe. One or two searches of this kind should bring about virtual certainty about the objective existence of the empty zone (μ).

Acknowledgements. We thank cordially A. Grossmann who helped us in the preparation of this text; G. de Vaucouleurs who brought to our attention the geometric and kinematic anisotropy of the Local Group; G. Burbidge, D. Kunth, P. Veron for data they gave us.

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Note added in proof: The spiral galaxies are generally envelopped by H I regions; the available data indicates a *very strong* correlation between the direction of these regions and the direction of stratification defined here. We are preparing a paper on this subject.