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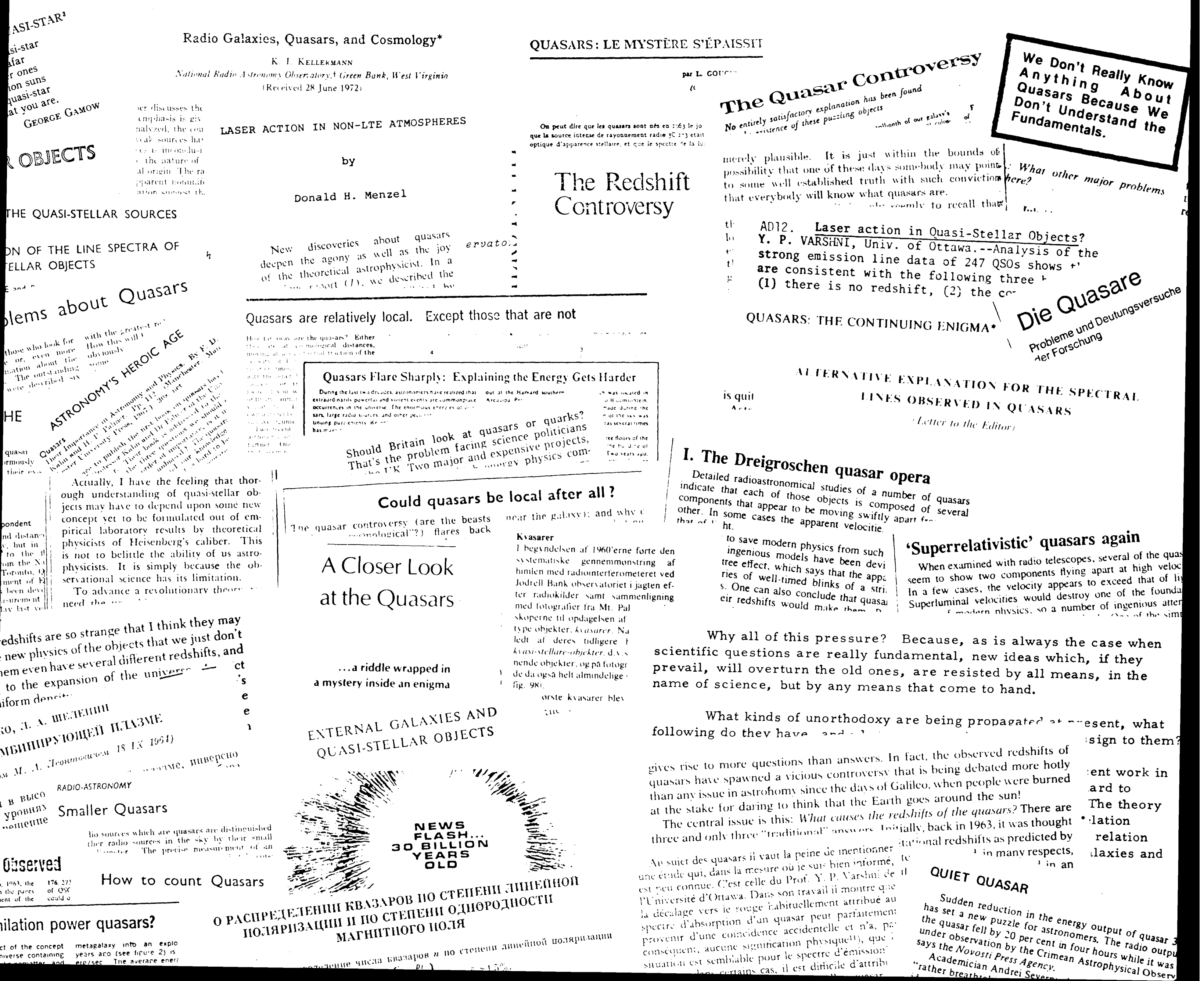

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"Fortunately, there is a growing tendency among physicists to recognize that astronomy is a part of physics ... ... there is every reason to regard astronomy as an integral part of physics." -O. Struve (1)

"Truth is ever to be found in simplicity, and not in the multiplicity and confusion of things." -Newton

"In questions of science the authority of a thousand is not worth the humble reasoning of a single individual." -Galileo

INTRODUCTION

Since their discovery, the nature of quasars has been one of most intriguing and baffling problems as evinced by the following quotations: ".... the problem of understanding quasi-stellar objects .... is one of the most important and fascinating tasks in all of physics." -G. Burbidge and Hoyle (2), "The quasar continues to rank both as one of the most baffling objects in the universe and one most capable of inspiring heated argument." -Morrison (3), "The redshift problem is one of the most critical problems in astronomy today." -G. Burbidge (4), " .... quasars still remain the profoundest mystery in the heavens." -Hazard and Mitton (5).

The conventional interpretation of the spectral lines observed in quasars is based on the redshift hypothesis. Three hypotheses have been advanced to account for these supposed redshifts: (a) Cosmological hypothesis; the redshifts are due to the expansion of the universe, (b) Gravitational hypothesis, and (c) Local-Doppler hypothesis; in this hypothesis the redshifts are due to the Doppler effect, but the quasars are relatively nearby and have nothing to do with the expansion of the universe. Of these three hypotheses, the first one is the most publicized one. Terrell (6) gives a good account of the difficulties present in the cosmological redshift hypothesis.

One is led to attribute to quasars very many mysterious properties if one assumes the redshift hypothesis to be correct. A patient analysis of the data on quasars over the years led the author to the conclusion that the real source of the trouble is in the assumption that the spectra of quasars have redshifts. In 1973 the author (7) proposed a radically different explanation of the spectra of quasars. In this paper we give the salient features of this theory (7-11) and compare it with the cosmological redshift hypothesis. For the sake of clarity we shall confine ourselves to quasars in this paper (" ... ... to divide each problem I examined into as many parts as was feasible, and as was requisite for its better solution." -Descartes (12), "To make progress in physics you should separate the difficulties and solve them one at a time" -Dirac (13)).

THE NEW THEORY

The explanation that we have proposed (7-11) for the spectra of quasars is based on sound physical principles and is free of any basic difficulty. The essential ingredients of the new explanation are: (1) There is no red shift, and (2) The strength of the emission lines is due to laser action (more specifically, due to amplified spontaneous emission). The term 'no red shift' here, of course, refers to the large red shifts claimed to occur in the spectra of quasars. Very small redshifts, $z < 2 \times 10^{-3}$, the type encountered in galactic stars, could certainly be present in the spectra of quasars. Furthermore, it is assumed that the chemical composition of the emission region of quasars is approximately the same as that of normal stellar atmospheres. This assumption is merely a first approximation and a convenient starting point. As our knowledge of quasars improves, this assumption can be suitably modified. The situation is somewhat similar to that of the Wolf-Rayet stars, for which our knowledge of their chemical composition has improved over the years but which is still in far from a satisfactory state. (There are good reasons to believe that quasars, like Wolf-Rayet stars, are deficient in hydrogen).

We enlarge upon the first two hypotheses in the following.

(1) Why is it assumed that the spectra have redshifts? The basic reason for this lies in the time-honoured assumption that the intensities of lines in astronomical sources will be similar to those in the laboratory under ordinary excitation conditions. No account is taken of a possible laser action. Thus, there is no compelling reason to believe in the redshifts if we allow the possibility of a laser action in these bodies.

(2) Gudzenko and Shelepin (14) proposed that if the free electrons in a plasma cool sufficiently rapidly, there can be a population inversion in the lower levels of an atom, and this can lead to laser action. Gudzenko,

Filippov and Shelepin (15) showed that such a rapid cooling can be achieved by expanding a plasma jet into a vacuum. The basic theory for obtaining the properties of a decaying plasma was given by Bates, Kingston and McWhirter (16) and is called the collisional-radiative model. A number of workers, using this model, have carried out calculations on the properties of a rapidly decaying monatomic plasma. The results obtained from a number of subsequent experiments for the recombination rates are for the most part in reasonable agreement with those calculated from the collisional-radiative model. Detailed theoretical calculations (17, 18) of the population densities of excited levels in a decaying hydrogen (and hydrogen-like ions) plasma flow predicted population inversions at electron densities ($n_e \sim 10^{13}$ to 10^{16} cm^{-3}) and electron temperatures ($T_e \sim 5000$ to 10^5 deg. K) with magnitudes which are very close to those existing in stellar atmospheres. The prediction regarding the inversion in the atomic level populations has been amply confirmed in several laboratory experiments (19). The subject has been reviewed by Gudzenko et al. (20).

Also, it is well known that in certain types of stars (Wolf-Rayet, P Cygni), matter is ejected more or less continuously.

We have thus proposed the following realistic model of a quasar: A quasar is a star in which the surface plasma is undergoing rapid radial expansion giving rise to population inversion and laser action in some of the atomic species. The assumption of the ejection of matter from quasars at high speeds is supported from the fact that the widths of emission spectral lines observed in quasars are typically of the order of 2000 - 4000 km/sec. We call the proposed model the plasma-laser star (PLS) model. Let us then examine the consequences of this model.

Detailed calculations on the properties of a rapidly decaying monatomic plasma have been carried out by a number of workers (17, 18, 21). The population densities of the excited levels are functions of the electron density (n_e), the electron temperature (T_e), and the density of the ground state atoms ($n(1)$). In stellar atmospheres, $n(1)$ is a function of n_e and T_e. Thus the state of plasma, after expansion, in a star can be represented by a point on a plot with n_e and T_e as axes.

It is found that for a given transition in a given atom, strong population inversion takes place only within a narrow area in the n_e, T_e diagram (see Fig. 1). This area is surrounded by a medium population inversion area, which in its turn is surrounded by a weak population inversion area. On the high n_e side, the boundary of the population inversion is rather steep. (Strong population inversion regions will give rise to strong lines, and similar statements hold for the medium and weak inversion regions.)

Now consider two wavelengths, λ_1 and λ_2, arising from different transitions in different atoms. We can represent their population inversion regions as shown in Fig. 2. We consider what will be observed if the emission-line region of a quasar corresponds to the different points shown on the diagram. Point 1: λ_1 strong, λ_2 strong; point 2: λ_1 strong, λ_2 absent; point 3: λ_1 weak, λ_2 strong; point 4: λ_1 strong, λ_2 medium, and so on. Thus a whole range of relative intensities is possible. We next consider the observational evidence relevant to this point. We have carried out a spectral classification of quasars. There are quasars which show two or more emission lines at practically the same wavelengths; such quasars were put together in a group. In the redshift interpretation, quasars belonging to the same group tend to have the same redshift. We give here three examples in which wide variations in relative intensities have been recorded; we have restricted ourselves to only such cases where the two quasars were investigated by the same astronomer(s) using the same telescope.

(a) 3C 309.1 and 0957+00. Spectra of both quasars were obtained by Lynds and his coworkers (22-24) on the Kitt Peak 84-inch telescope, and are reproduced in Fig. 3. Both quasars show two emission lines at 3640

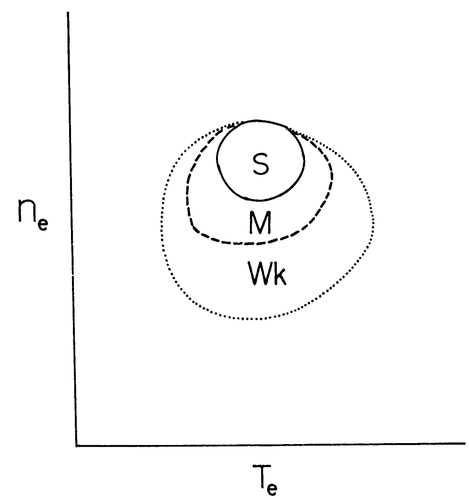

Fig. 1 Population inversion region for a transition. The solid, dashed, and dotted curves show strong, medium, and weak population inversion regions, respectively. The diagram is purely qualitative. n_e and T_e are on a logarithmic scale.

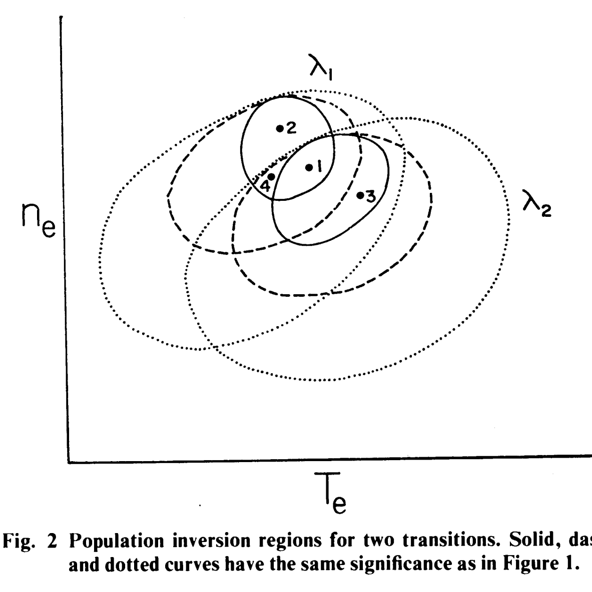

Fig. 2 Population inversion regions for two transitions. Solid, dashed, and dotted curves have the same significance as in Figure 1.

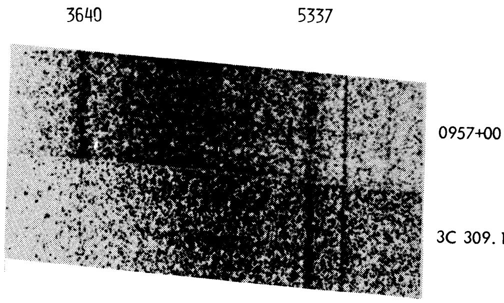

Fig. 3 Spectra of two quasars, 0957+00 and 3C 309.1 (ref. 24). The sharp emission line at the extreme right is the night sky line λ5577.

(±5) Å and 5337 (±5) Å repsectively. λ3640 is stronger than λ5337 in 0957+00, but λ3640, is quite weak in 3C 309.1, in which λ5337 is very strong.

(b) 3C 208 and 3C 204. Spectra of both quasars have been obtained by Schmidt (25) on the 200-inch telescope. λ4030 is of medium strength in both the quasars, but λ3275 is medium in 3C 208, and weak in 3C 204.

(c) 1508-05 and 2329-384. Spectrograms for both the quasars were obtained by Peterson and Bolton (26) on the Mount Stromlo 74-inch telescope. λ4185 is strong in both the quasars. On the other hand, another line, λ3396 is strong in 2329-384, but weak in 1508-05.

It is obvious that these results are in strong support of the PLS model regarding the relative intensities of emission lines. Varshni and Lam (27) have presented model calculations for laser action in He II λ4686 within the framework of the PLS model.

COMPARISON

Next we compare the performances of the cosmological redshift hypothesis and the PLS model in explaining the various pieces of evidence on the nature of quasars. We shall divide these into two broad categories: optical and radio observations.

OPTICAL OBSERVATIONS

1. Emission Spectra

Do the redshifts really exist? It is of vital importance to examine whether there is incontrovertible observational evidence in favour of the redshifts. More specifically, we raise the question whether the numerical coincidences found between the ratios of wavelengths of lines observed in quasars and those of the wavelengths given in the search list of lines, are significantly more than would be expected from chance coincidences. We have carried out investigations (9, 28) in the spirit of the paper of Russell and Bowen (29) to examine this question. Quasars having $z \geqslant 0.2$ were considered. Computer experiments to simulate the spectra of two-emission-line quasars were made, about 80% of these nonsense spectra could be assigned reasonable redshifts.

The PLS Model We have shown above that the PLS model for quasars predicts large variations in the relative intensities of lines undergoing laser action. Given the appropriate conditions, laser action is possible in a great many spectral lines. Thus it is readily seen that quasars can be expected to show a great variety of spectra, which indeed is the case.

The Wolf-Rayet stars show broad emission lines, quite similar to those of quasars. Analogy is a powerful tool in science, and for identifying spectral lines in quasars, it is obviously of interest to compare such quasars and Wolf-Rayet stars which may have similar spectra.

Some planetary nuclei show Wolf-Rayet type of spectra. Smith and Aller (30) have classified the emission line spectra of planetary nuclei in five classes - one of these is called the 'O VI sequence'. The defining characteristic of this class is the presence of emission lines due to the O VI doublet λλ3811, 3834 among the strongest lines in the spectrum. In addition, emission lines C IV λ4658 and He II λ4686 are also present and are usually of comparable intensity to the O VI lines. Smith and Aller (30) have listed 12 such planetary nuclei. It was pointed out by Sanduleak (31) that this variety of Wolf-Rayet like spectrum (O VI sequence) also occurs in stars that do not appear to be planetary nuclei. He provides a list of five such stars.

In the course of our analysis of the spectra of quasars, we have found (11) that there are at least fourteen quasars whose emission line spectra (as observed, no redshift) belong to the O VI sequence. (In reference 11, only 10 such quasars were reported, an additional 4 were found subsequently). In Figure 4 we show a diagrammatic representation of the spectra of three of the planetary nuclei (NGC 6905, NGC 7026, and NGC 5189), two of the Sanduleak stars (Sand 1 and Sand 4), and ten of the quasars, belonging to the O VI sequence. (Only the strong lines in the spectra of planetary nuclei and Sanduleak stars are shown.) The continuity and similarity between the spectra of these objects is obvious. We do not require any redshifts to identify the spectral lines in planetary nuclei and Sanduleak stars; we fail to see any reason why one should invoke empty multiplying numbers to identify the spectral lines in quasars. Reference 11 gives details of identifications of quasar lines shown in Fig. 4.

2. Absorption Spectra

At present, absorption lines are known to exist in the spectra of some 50 or so quasars. About half of them show a rich absorption line spectrum. Such spectra have been interpreted on the redshift hypothesis by assuming multiple redshifts. The number of redshift systems proposed to account for these absorption lines is becoming comparable to the number of epicycles required (in a different era) to save the geocentric system of the solar system -- in one case (0237-23) as many as 45 redshift systems have been proposed. Varshni (32-34) has discussed the spectra of the quasar 4C 05.34 in detail and has shown that the number and properties of the proposed absorption redshift systems are insignificantly different from those that would be expected from chance coincidences.

The absorption lines which occur in the spectra of quasars can be conveniently classified in four categories.

(a) Sharp and deep absorption lines, resembling those in a shell star.

(b) Unusually strong lines, quite often having several components.

(c) Very wide (∿30 Å) absorption lines.

(d) P Cygni lines, i.e., emission lines accompanied by shortward displaced absorption lines.

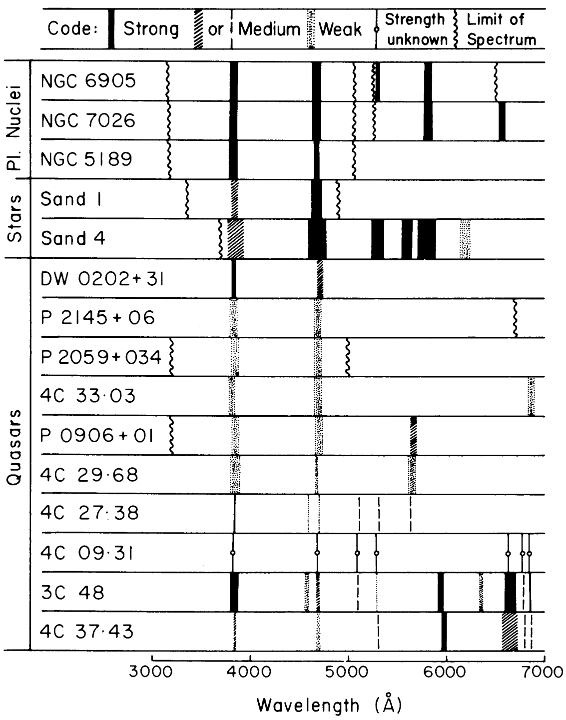

Fig. 4 Diagrammatic representation of the spectra of the following : (A) Central stars of three planetaries, (B) Stars Sand 1 and Sand 4, and (C) Ten quasars. The code for the strengths of the lines is explained at the top of the diagram. The wavy vertical lines indicate, where known, the limit(s) of the observed spectrum.

We have compared (35, 36) the expected shell spectrum of a quasar on the basis of the PLS model with the observational data. The absorption lines arising from ordinary excited levels will be very weak as these levels will be strongly underpopulated. The populations of metastable levels below the first ionization potential and those of the Wu levels will be enhanced due to the dilution of stellar radiation. Consequently, lines arising from these levels are expected to be prominent. We expect that category (a) lines should mostly arise from transitions from metastable states below the first ionization potential. The ions and their levels which would be most important would, of course, depend on the degree of excitation of the shell. Lines due to metallic ions like Sc II, Ti II, Mn II, Fe II, Cr II etc. are known to occur frequently in the spectra of "classical" shell stars. In addition, He I and Fe III lines occur in some shells in which the ionization level is higher. Extrapolating, we can expect the presence of He I, Fe III, Ti III, Ar II, Al III, Si III, Mn III, O II, O III etc. in the shells of quasars, if the ionization level is still higher.

For identifying spectral lines, one would like to have an accuracy of 0.1 Å or better in the observed wavelengths, a moderate accuracy in their intensities, and to have these data over a wide wavelength interval. However, most of the reported data are of poor accuracy - the claimed accuracy varies between 1 Å and 2 Å. When interpreting these data on the redshift hypothesis, usually most authors allow a discrepancy of ± 2 Å and it would appear that most of the data have this sort of uncertainty. Also, in many cases, the mutual blending of lines is very severe. If one had a spectrum of an ordinary star of this quality, it would be prohibitively difficult to identify the lines, except those of hydrogen and Ca II. (Quasars, being deficient in hydrogen, do not show the hydrogen lines). We may note here that He I λ3889,which is a prominent line in certain shell stars, also occurs in the spectra of PHL 957, 1331+170, 4C 25.05, PHL 5200, PKS 0237-23, and 1158+122. Lines arising from the Wu states will be difficult to identify as very few of these have been observed in the laboratory.

3. Energy generation mechanism

It is well known that in the cosmological hypothesis one is faced with the difficult problem of finding the origin of the very large energies released. No satisfactory solution to this question has been found so far. The presumed high luminosity of quasars is, of course, a consequence of the cosmological interpretation of the redshift. In the PLS model, a quasar is just a special type of star and there is no difficulty as regards the energy generation mechanism. (Good old nuclear reactions!)

4. Optical variability

It is well known that the optical variability of quasars and the arguments which follow from the size limits set by the variability, pose a serious difficulty for the cosmological interpretation (37, 38, 4). Very small sizes lead to a paradoxical situation in models for very high luminosities (37). Several ingenious, though rather top-heavy, models have been suggested to get around this difficulty. To quote G. Burbidge (4): "In spite of impressions to the contrary, nobody has published a well worked out model in which they can account for the continuum source properties and avoid this paradox if the QSO is at a cosmological distance."

The PLS model faces no such difficulty. Variable stars have been known for a pretty long time.

5. Redshift-Apparent Magnitude Diagram

It is well known that the redshift-apparent magnitude diagram for quasars is a scatter diagram. Fig. 5, which is reproduced from G. Burbidge (39), shows the plot of redshift versus the apparent magnitude for

570 quasars. According to our theory these so called "redshifts" are just empty numbers without any physical significance. Naturally, no correlation with the apparent magnitude is expected.

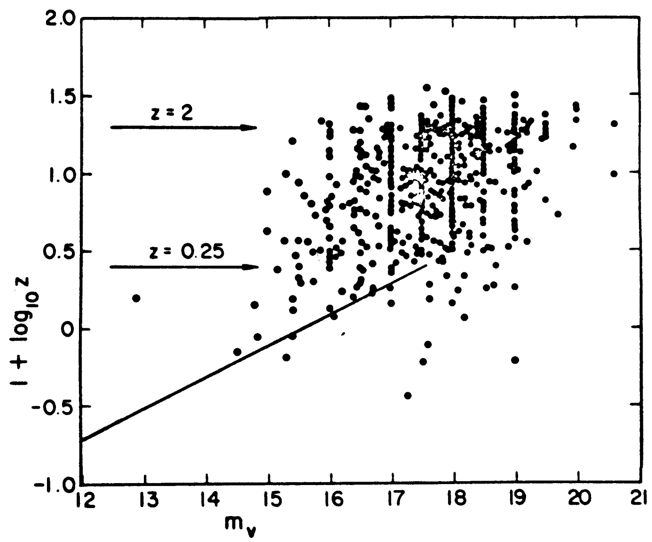

Fig. 5 Redshift-apparent magnitude diagram for 570 quasars (from ref. 39).

6. Coincidences in redshifts

We have classified quasars on the basis of their spectra (40). There are a large number of groups of quasars where two or more quasars have very similar spectra. Consequently, quasars belonging to each of these groups have almost identical redshifts. (Quite often there is a small dispersion in the redshift values, because of several reasons, the primary one being large uncertainties in the measured wavelengths). As an illustration, in Fig. 6, we show a diagrammatic representation of the spectra of quasars belonging to group 18 of our classification. We have shown that the probability of the occurrence of such coincidences in redshifts by chance is very small (40, 41).

If we try to interpret these coincidences, assuming the cosmological redshift hypothesis, we find that the quasars in the various groups are arranged on spherical shells with the Earth as the center (40, 41). In other words, the earth is the center of the universe. It is no doubt an amazing result and those, who, like Einstein, believe in the importance of aesthetic elegance and inner perfection of a good theory, would consider this result an adequate ground to reject the cosmological redshift hypothesis.

7. Lyman-α absorption in intergalactic hydrogen

On the cosmological hypothesis one expects continuous absorption at wavelengths below the Lyman-α emission (42, 43). We illustrate it taking 3C 9 as an example. 3C 9 has a redshift of 2.012 so that the strong Lyman-α line of hydrogen, which is normally observed at 1216 Å, is shifted to 3663 Å. The intergalactic neutral hydrogen density is estimated, by indirect methods, to be about 10^{-29} g/cm^3. The passage of continuum radiation through this hydrogen will give an absorption line at 1216 Å. In the case of distant objects like 3C 9 sufficient hydrogen should be traversed to give a detectable effect. Since the radiation from this distant quasar is red-shifted, the absorption will be evident not as a line but as a general deficiency of continuum radiation at wavelengths between 1216 and 3663 Å. The absorption takes place at 1216 Å but the photons absorbed would arrive at the earth at a wavelength shifted by an amount appropriate to the distance between the point of absorption and the earth. Observational measurements have shown no absorption. Our theory resolves this problem quite easily. Galactic stars are not expected to show any such absorption and neither are quasars.

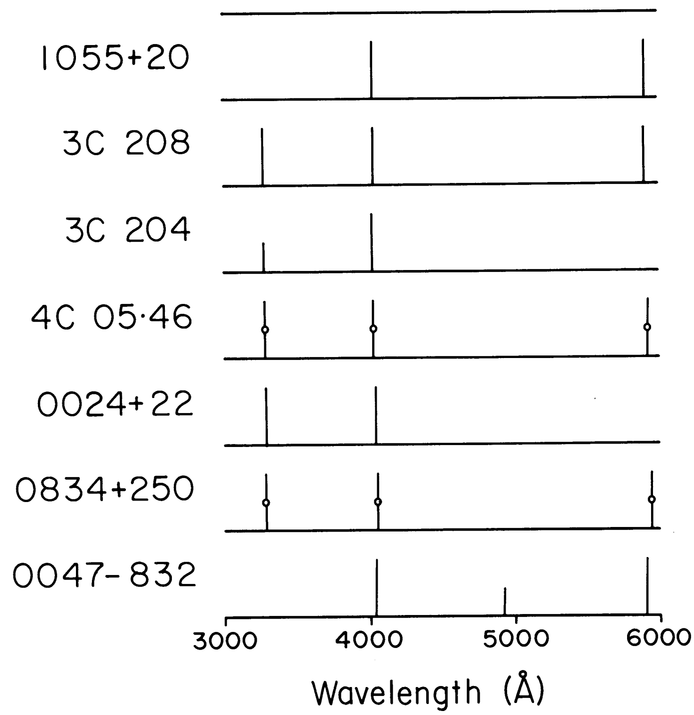

Fig. 6 Diagrammatic representation of the spectra of 7 quasars belonging to the group 18. The heights of the lines represent their strengths, except for 4C 05.46 and 0834+250, for which the observers have not given the strengths of lines. (2/3)rd height indicates medium strength, (1/3)rd, weak. The spectrum of 1055+20 has not been investigated below 4000 Å, that of 0047-832, not below 3500 Å, and that of 3C 204, not above 4950 Å. Notice that the line at ~ 5900 Å is very close to the night sky line λ5893.

8. Proper Motions of Quasars

Our hypothesis that quasars are stars raises the question of their proper motions. We have noted earlier that there is a continuity in the optical spectra of ten quasars and those of O VI sequence planetary nuclei and stars. A detailed comparison suggests that there is some relationship between quasars and planetary nuclei. This, in turn, suggests that the proper motions of these two types of objects may be comparable. Proper motions of a few quasars have been discussed by Luyten and Smith (44) and Sanders (45). Luyten (46) has determined the proper motions (absolute) of 951 faint blue stars. We have searched (47) for quasars in Luyten's list and have found that there are 30 quasars, in addition to those considered in references 44 and 45, for which proper motions are known. The proper motions of those 30 quasars were calculated from their component values. There are three quasars which have proper motions comparable to the largest value amongst planetary nuclei. These three quasars and their respective proper motions (in yr^{-1}) are PHL 1033: 0".049 ± 0".013, LB 8956: 0".061 ± 0".018, and LB 8991: 0".050 ± 0".018. These values may be compared with the largest proper motion reported up to now for a planetary nebula, which is 0".040 ± 0".003 yr^{-1} for NGC 7293 (believed to be the nearest planetary nebula). The distance of NGC 7293 is estimated to be 212 pc; from this it would be reasonable to estimate that the quasars PHL 1033, LB 8956 and LB 8991 lie within a few hundred parsecs from the sun.

RADIO OBSERVATIONS

9. Double Source Structure

A comparison of the optical and radio maps of the same region of the sky shows that for many quasars, there are radio sources in their vicinity. Morphologically, these sources can be broadly divided in the following two classes (48): D - A double source consisting of two well-separated regions. There are two sub-classes, D1 denotes a double source with neither of its components coincident with the optical quasar. (3C 47 is a well known example of this class). D2 denotes a double source for which one of its components coincides with the optical quasar. C - A complex source consisting of three or more components. A majority of quasars belong to the D class. The fact that such radio sources occur in close proximity to quasars on the two dimensional map of the sky is usually taken to imply that these sources are associated with quasars. According to the cosmological folklore, such double sources are supposed to occur only with quasars or radio - "galaxies". In Fig. 7(a), we show 3C 47 (ref. 49), the + denotes a quasar, and in Fig. 7(b), we show 3C 435 (ref. 50), the + denotes a galactic star (50, 51). The similarity in the two cases is obvious. The evidence for the association of 3C 435 with the star in the middle is as good (or as bad) as that of 3C 47 with the quasar in the middle. There are at least two other stars, Sco X-1 and AD Leo, which are flanked by double radio sources.

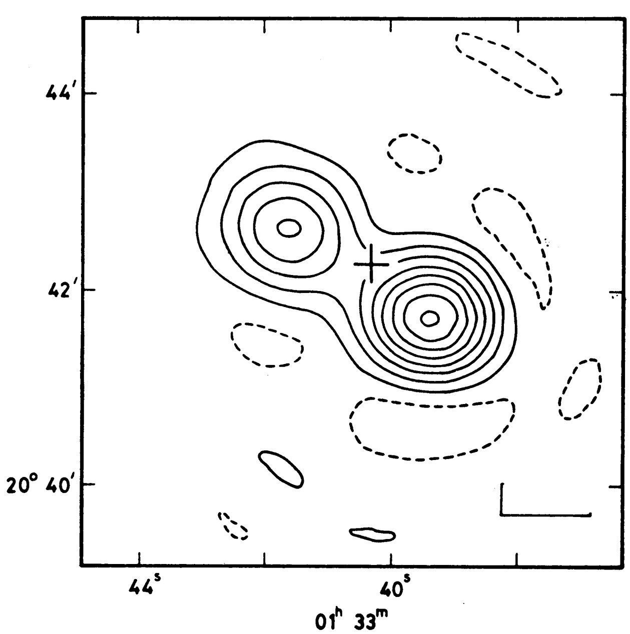

Fig. 7(a) Two components of the radio source 3C 47 and the quasar (indicated by a +) in between (from ref. 49).

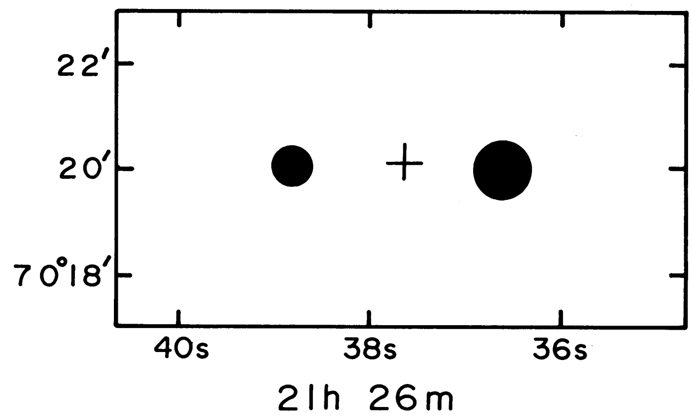

Fig. 7(b) Radio source 3C 435. Filled circles indicate the positions of the radio peaks, the larger spot indicates the brighter component, + indicates the position of a star (after ref. 50).

10. Apparent "Superrelativistic" Expansion

In recent years radio-astronomers have used very-long-baseline interferometry observations to probe the fine structure of quasars. For three of the quasars, namely 3C 273, 3C 279 and 3C 345, it has been found that there are two components very close to the quasar and that the angular separation of the two components is increasing with time (52-54). If this angular expansion is interpreted in terms of the cosmological hypothesis, it corresponds to an apparent speed of expansion, which is between 2 to 10 times the speed of light. In other words an apparent "superrelativistic" expansion. It is, of course, a consequence of placing the quasars $\sim 10^9$ pc away. On our theory, quasars being stars, are only ∿5 kpc away, and the corresponding speed of expansion assumes a very modest value. Recent results (53, 54) show that for 3C 345 the rate of increase of angular separation of the two components is ≃ 0".00015 per year. This value may be compared with the rate of increase of the angular radius of Crab nebula (distance ∿ 1 kpc), which is 0".235 per year (55).

11. Largest Angular Size -Redshift diagram

The angular size of a radio source is a particularly sensitive test of cosmological models (56), since for Friedmann models a source with linear diameter D will reach a minimum angular diameter near a redshift ≃1; the exact value of the minimum and the shape of the angular diameter-redshift curve depend on the parameters of the model.

The largest angular size (LAS)-redshift(z) diagram has sometimes been used as an argument in favour of the cosmological interpretation of the apparent redshifts of quasars. It is important to establish whether or not the existence of the envelope is real or whether it arises because of some statistical or selection effects. We have demonstrated (57) that the observed behaviour of the envelope of the LAS-z plot is a consequence of statistical effects and is just a reflection of the redshift distribution diagram, and that it has no intrinsic physical significance. Prior to our analysis, it was thought that the component size decreases with increasing redshift. Our analysis showed that if the LAS is measured for a good number of large redshift quasars, some of them will show a large LAS. This has been confirmed at least for one quasar (58).

CONCLUSION

The above discussion clearly demonstrates that quasars are stars and that the PLS model provides satisfactory explanations of the various phenomena associated with quasars. The redshift hypothesis is nothing more than an exercise in empty numerology (59).

In fairness to Schmidt (60), we note here that he recognizes that "If the cosmological hypothesis is correct, it is remarkable indeed that no single independent confirmation of the large distances exists as yet". How can there be any confirmation, when there are no redshifts?

The real importance of quasars lies in the beautiful physics they involve, leading to a display of phenomena of unparalleled splendour.

"The problems immediately confronting the astrophysicists of the twentieth century are serious ones. They call for our best efforts. The volume of work demanded is stupendous, and the difficulties to be overcome are correspondingly great. Nevertheless, the men and the means will be forthcoming."

- W.W. Campbell (1905)

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