accounted for completely in terms of a hydrogen nebula with an electron temperature of 160 000°K. A second possible interpretation is that this radiation is due to a hydrogen nebula at a temperature of 14 000°K; in this case it is necessary to arbitrarily add a flat continuum of unknown origin, which must account for 93 per cent of the continuous radiation. The observed light fluctuations require, in both models, that the size of the object be a few parsecs or less and the mass of the order of 10^7 $M_\odot$. At the density implied by such a model electron scattering becomes sufficiently important that light variations are difficult to explain.

(A full account has been published in the *Astrophysical Journal*, **141**, 6, 1965).

5. LIGHT VARIATIONS OF QUASI-STELLAR SOURCES

H. J. Smith

Photo-electric work by Sandage (**1**) has shown distinct optical variability of several tenths of magnitude, at least over time scales of months in 3C 48, 3C 196, and (supported by McDonald observations) in 3C 273 as well. But we lack long enough photo-electric histories of variation to see what patterns, if any, may exist. Fortunately, a great many historical photographs in various collections permit reasonably accurate tracing of the history of 3C 273 from 1886 to the present. Some details of such an analysis will appear shortly (Smith (**2**)); accordingly, the present note is a brief abstract only.

Fig. 1 is a mean light curve based on over 2000 unweighted magnitudes determined by some ten workers at various observatories, but mainly by D. Hoffleit and the author from Harvard plates, with major collections of additional points prior to 1930 from E. Geyer at Heidelberg and after 1950 from H. Huth at Sonneberg. About 500 of these same plates have also been measured by iris photometry, giving a less detailed but more accurate curve (Fig. 2). Variations have a total amplitude of about 0·7 magnitude, with apparent flash points reaching more than half a magnitude brighter yet. While some of the variation is of an apparently rather chaotic character, after 1929 a sudden sharp drop of half a magnitude seems to lead into a strongly marked quasi-periodic variation with period more than a decade.

The fact and general nature of the light variation constitute the only essential feature of this paper. But in trying to visualize an object which could produce such fluctuations, I have speculated as to whether the light curve could also be read as originating in part from damped oscillations of a very massive starlike body. On this picture most of the optical emission lines and radio emissions would presumably arise in successively more extended outer regions, not necessarily directly relevant to variations at the hypothetical 'photosphere' of such an object.

In particular, at the Dallas Symposium on Gravitational Collapse I had remarked that three points might be noted as consistent with the presence of a central body having very rough order-of-magnitude dimensions and mass of 2×10^{16} cm and 10^6 $M_\odot$ respectively. First, the apparent flash so far found to have shortest duration, and supported by several consistent iris photometer observations, is a 1929 event indicating a 10-day rise of 0·7 magnitude and a total duration of 4 weeks. If this event is real, light travel time sets an upper limit of less than 10^{17} cm for the size of the region undergoing the brightening. Secondly, if this region is associated with the core of the object, and if a significant share of the continuum originates from an effective photosphere of temperature in a range generally commensurate with the color indices, then a surface again a few times 10^{16} cm is required to produce the large absolute magnitude of 3C 273. Finally, a mass of some 10^6 $M_\odot$ within such a radius would, by application of the simple

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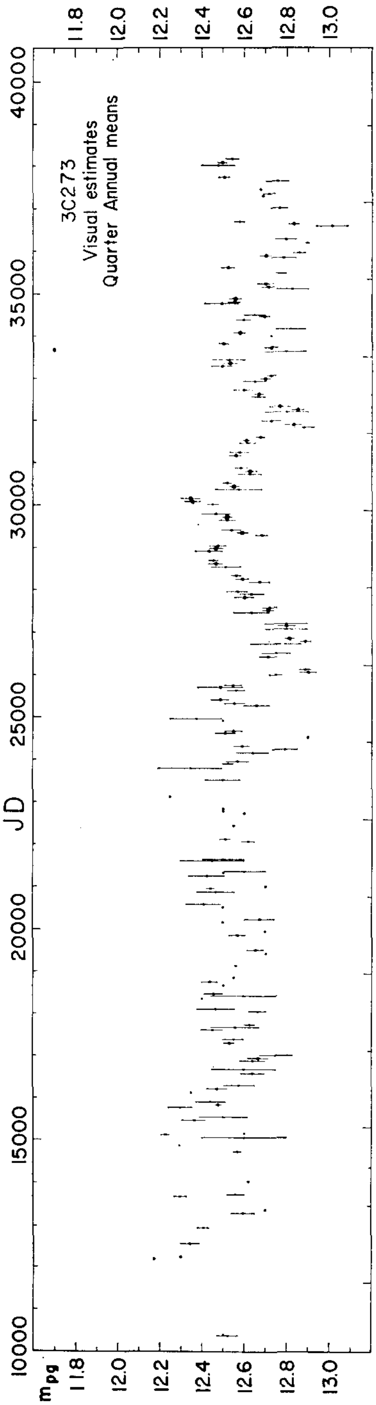

FIG. 1

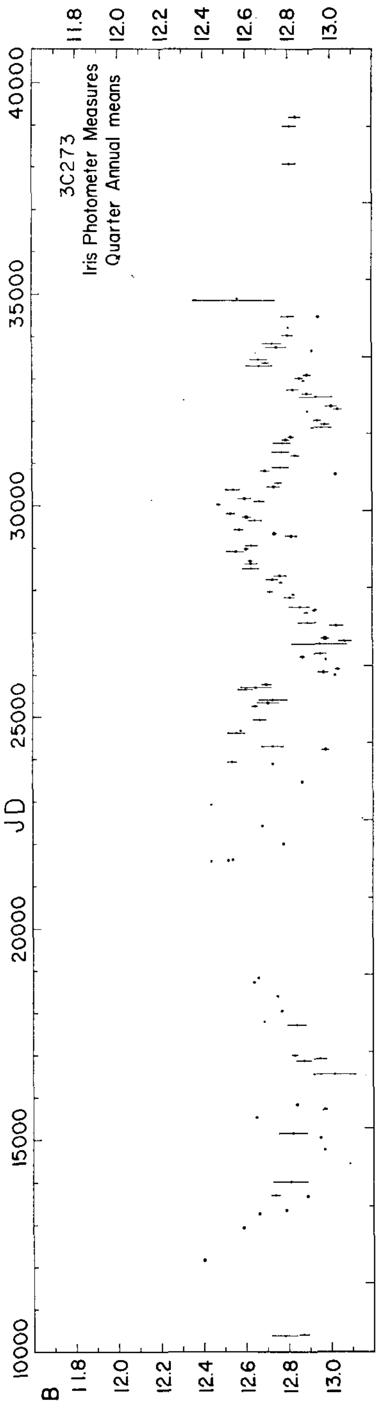

FIG. 2

x

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$P(\rho)^{\frac{1}{2}}$ relation (if β could be near unity), give a density in the range 10^{-10} cgs and a fundamental period near 10 years, where indeed much of the power in the frequency spectrum of 3C 273 is concentrated. But Fowler and others have pointed out that β is not likely to be greater than 10^{-3}, in which case the problem for this hypothesis becomes one of finding any set of parameters for which pulsation of such a massive object is possible.

REFERENCES

1. Sandage, A. *Astrophys. J.*, **139**, 416, 1964.
2. Smith, H. J. Proceedings Dallas Conference on Gravitational Collapse (University of Chicago Press), 1964.

DISCUSSION

J. Greenstein. Interpretation of the quasi-stellar sources requires a considerable sophistication. First, note that variations (flashes) in 10 days do require motions at the speed of light if the scale is too near 10^{16} cm; these will be difficult on any theory. Similarly, the difficulties to be noted in an over-simple treatment of pulsation in massive objects are very real. Even in main-sequence stars the correction to the density caused by radiation pressure is large since the latter is dominant. Also, if the mass is as high as required, the relativistic corrections are large. In other words, a large change in the $P(\rho)^{\frac{1}{2}}$ law is required.

Returning to the observational interpretation, the radius is deduced from the luminosity by means of the black-body law and the assumed temperature, taken by Smith as a normal stellar temperature. If the continuum observed is not a black body—if it is largely hydrogen recombination—the black-body law should not be used.

H. J. Smith. While there are difficulties with any theory of quasars, Greenstein's remarks are of course correct. The pulsation suggestion may prove entirely unfounded, and even if partly true would leave much to be interpreted. But it does offer several predictions, especially that of the future behavior of the light curve as an extrapolation from the quasi-periodic behavior observed particularly after 1929, also that a substantial part of the continuum should fluctuate in brightness against a relatively constant set of emission-line intensities.

6. SOME REMARKS ON THE NATURE OF THE NUCLEI OF GALAXIES

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There is no doubt now that the phenomenon of radio-galaxies is closely connected with the processes going on in the nuclei of galaxies. Therefore it seems appropriate to make here some general remarks on the nuclei of galaxies.

In our Solvay report of 1958 and Invited Discourse in Berkeley (1961) we have tried to show that we can reduce many phenomena we observe now in galaxies to the *activity of nuclei*. It was supposed that owing to this activity the nuclei play an essential role in the formation and evolution of corresponding galaxies. At that time the general impression was that we overestimate strongly the part played by nuclei in the evolution of galaxies. But in the light of recent developments it seems to me that we were rather cautious in this respect.

Our information about the processes in radio-galaxies is still very restricted. Nevertheless we can say definitely that the phenomenon of a radio-galaxy is to be considered as one of the forms of the activity of a nucleus.

There are also several other forms of the activity of nuclei of galaxies. For the description of them I refer to my Berkeley Discourse.

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