LETTERS TO THE EDITOR

ASTRONOMY

Optical Variations in 3C 446

Cannon and Penston[1] have reported observations of the rapid optical fluctuations of the quasi-stellar object 3*C* 446. These add further to the study of rapid variations discovered in this object by Sandage[2] and followed in 1966 by Kinman, Lamla and Wirtanen[3]. Variations of this kind lead to the conclusion that the region which gives rise to the fluctuation is very small, and in general it is found that for this region $R \leqslant c\tau$, where τ is the period over which a flux change has occurred. A detailed discussion of this result has been given by Terrell[4] and others. These limitations lead to very restrictive conditions on the possible models of quasi-stellar objects which arise largely from the high radiation density that must be present in the continuum source. The upper limits to the sizes which have been used range from light months to light days ($\sim 10^{17} - 10^{15}$ cm) and the corresponding lower limits to the energy densities are then in the range 10–10^5 erg/cm^3 if the quasi-stellar objects are at cosmological distances, and 10^{-3}–10 ergs/cm^3 if the objects lie at distances ~ 10 megaparsec (Mpc). If the objects are at cosmological distances, then this radiation field is so intense that it would be self-destructive, whether it arises by the synchrotron process or from the inverse Compton process[5,8]. The difficulties that are encountered in arriving at satisfactory models, if the quasi-stellar objects are at cosmological distances, have been considered by Hoyle, Burbidge and Sargent[5]. Attempts to evade or to minimize these difficulties if the objects are at cosmological distances have been made by Rees[6], by Woltjer[7], and by Hoyle and Burbidge[8], and they require that the radiating blobs are moving at relativistic speeds and/or that there is a large degree of directivity in the streams of relativistic electrons. If the quasi-stellar objects are much closer, the radiation density is accordingly reduced and the problems are less severe.

Cannon and Penston have now attempted to account for the variations seen in 3*C* 446 by a mechanism which at first sight does not appear to require such extreme conditions. They argue that the small central continuum source is radiating at a constant rate, but that it is obscured from time to time by absorbing clouds which are moving at velocities of a few thousand km/sec but which are gravitationally bound to the system. They think that the masses and the velocities of the clouds are not excessively high. In order for variations to take place by clouds passing in front of the continuum sources at such low velocities, however, they must assume that the dimension of the central source $R < 7{\cdot}5 \times 10^{13}$ cm or about 40 light minutes. Thus, while the parameters of their absorbing region may be reasonable, the energy density which must be contained in the central object is now even higher than that which causes grave difficulties in the previous models. If the quasi-stellar objects are cosmological as they assume, these energy densities now reach the fantastic value of 2×10^7 ergs/cm^3, and the previous discussions of the inverse Compton effect[5,8], in such an object, lead me to the conclusion that such a model must be rejected.

Independent evidence has recently been given which strongly suggests that the red-shifts of the quasi-stellar objects are intrinsic red-shifts and that the objects are therefore not at cosmological distances[9,10]. Even if they are at distances as close as 10 Mpc, however, a size $R \leqslant 7{\cdot}5 \times 10^{13}$ cm leads to radiation densities $\geqslant 10^3$ ergs/cm^3, and all the difficulties inherent in the early discussion which may only be avoided by making extreme assumptions[6–8] remain. Consequently, I conclude that the model proposed by Cannon and Penston is exceedingly improbable unless the quasi-stellar objects are objects in or just outside our own Galaxy.

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[1] Cannon, R. D., and Penston, M. V., *Nature*, **214**, 256 (1967).
[2] Sandage, A. R., *Intern. Astro. Union Circ.* No. 1961 (1966). Sandage, A. R., Westphal, J. A., and Strittmatter, P. A., *Astrophys. J.*, **142**, 322 (1966).
[3] Kinman, T. D., Lamla, E., and Wirtanen, C. A., *Astrophys. J.*, **146**, 964 (1966).
[4] Terrell, J., *Astrophys. J.*, **147**, 827 (1967).
[5] Hoyle, F., Burbidge, G. R., and Sargent, W. L. W., *Nature*, **209**, 751 (1966).
[6] Rees, M. J., *Nature*, **211**, 468 (1966).
[7] Woltjer, L., *Astrophys. J.*, **146**, 597 (1966).
[8] Hoyle, F., and Burbidge, G. R., *Nature*, **212**, 1223 (1966).
[9] Burbidge, G. R., *Astrophys. J.*, **147**, 851 (1967).
[10] Burbidge, G. R., and Burbidge, E. M., *Astrophys. J.*, **148**, *L*107 (1967).

PLANETARY SCIENCE

Magnetic Declination in Mediaeval China

THE traditional view that Christopher Columbus discovered magnetic declination on his first voyage to the West Indies in 1492 was put forward with great force by Bertelli[1] towards the end of the last century and has been repeated by many since. On the other hand, Crichton Mitchell[2], after having examined the evidence on which this claim was based, concluded that not only did Columbus not discover magnetic declination but that the existence of declination was known in Europe as early as 1450. In the past few decades, however, the Columbus controversy has become irrelevant with the researches of Wang Chen-To[3] and Needham[4], who have shown that the credit for the discovery of declination must go to the Chinese. Needham, in particular, has tabulated eighteen recorded Chinese compass observations of declination covering the period about 720–1829. These are of interest not only to historians but also to geophysicists, for they represent the earliest recorded direct observations of the Earth's magnetic field. The question of their validity is therefore of great importance.

Table 1. CHINESE COMPASS OBSERVATIONS OF DECLINATION 720–1829[4]

Date A.D.	Place of observation	Latitude N.	Longitude E.	Declination
c. 720	Chhang-an (Sian)	34° 16′	108° 57′	3–4° E
c. 850	Probably Sian	34° 16′	108° 57′	*c.* 15° E
c. 900	Probably Sian	34° 16′	108° 57′	*c.* 7·5° E
c. 1030	Probably Khaifêng	34° 52′	114° 38′	Slightly W
c. 1086	Khaifêng	34° 52′	114° 38′	5–10° W
1115	Khaifêng	34° 52′	114° 38′	*c.* 15° W
c. 1174	Hangchow	30° 17′	120° 10′	5–10° W
c. 1230	Probably Hangchow	30° 17′	120° 10′	7·5° W
c. 1280	Probably Hangchow	30° 17′	120° 10′	7·5° W
c. 1580	Probably Peking	39° 54′	116° 28′	*c.* 7·5° W
c. 1625	Peking	39° 54′	116° 28′	5·5–7·5° W
c. 1680	Nanking	32° 4′	118° 47′	3° W
c. 1680	Suchow	31° 23′	120° 25′	2·5° W
1690	Canton	23° 8′	111° 16′	2·5° W
1708	Shanhaikuan	40° 2′	119° 37′	2° W
1708	Chiayükuan	39° 49′	98° 32′	3° W
1817	Canton	23° 8′	111° 16′	0
1829	Peking	39° 54′	116° 28′	1·5° W

The Chinese declination values quoted by Needham are shown in Table 1. The first of these, made by I-Hsing about the year 720, was quoted by Wylie[5]; but he gave no reference, and the text has since then been sought by sinologists in vain. We have now, however, struck a trail which leads back as far as 1713. The words translated by Wylie are found in the *Chhou Jen Chuan* ("Lives of Mathematicians and Astronomers") published in 1840 (chapter 52, page 707) under the entry for Chang Tso-Nan*, from whose *Chhuai Yo Hsiao Lu* ("Modest Results with the Key of Measurement"), a book of astronomical

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