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COMMENTS ON GOTT AND GUNN'S SOLUTION OF DOUBLE QUASARS

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ABSTRACT

The explanation offered by Gott and Gunn for the double quasar 1548+115—namely, that the gravitational lens brightening of faraway quasars by foreground quasars increases the chance of finding more pairs of quasars—is examined and shown to be incorrect.

Subject headings: gravitation — quasi-stellar sources or objects

The brighter component of the double quasar 1548+115 discovered by Wampler *et al.* (1973) is a 17 mag object, while the fainter component is 19 mag. To date about 70 quasars are known which are brighter than 17 mag; and according to Sandage and Luyten (1969) there should be 1.8 quasars per square degree brighter than 19 mag. Thus, when searching for a second quasar in close vicinity of the 70 bright quasars, there should be a probability of 8×10^{-4} to find within 5″ from one of them a second quasar which is brighter than 19 mag. In view of this very small chance of finding a companion, the double quasar discovered by Wampler *et al.* constitutes a puzzle: it suggests that the closeness of the two quasars cannot be merely a chance occurrence, but that there has to be some physical connection between the two.

Gott and Gunn (1974) have proposed an explanation for this puzzle. The explanation is based on six assumptions: (1) the redshifts of both components of the double quasar are cosmological; (2) both components are genuine superluminous objects; (3) the quasar Q_1, i.e., 115a ($z = 0.4359$) is the nucleus of a giant galaxy of $4\text{–}7 \times 10^{12} M_{\odot}$; (4) this giant galaxy is not visible on the photographic plates, because of the great brightness of the quasar at its center; (5) the giant galaxy (or its halo) acts as a gravitational lens on the quasar Q_2, producing thereby an intensified image which is seen as 115b; (6) to act as a lens, the quasar Q_2 ($z = 1.901$) cannot be at a distance of 5″, but has to be at a distance of about 1″.25 from quasar 115a (see their Fig. 2).[1]

In computing the amplification and deflection of the gravitational lens, Gott and Gunn use a formalism which, they say, has been developed by Press and Gunn (1973) for gravitational lens problems in expanding cosmologies. The method published by Press and Gunn is identical with the method developed by Refsdal (1966), and later adapted to particular problems by Barnothy and Barnothy (1968), Sanitt (1971) and de Silva (1972), with the exception that the distance $\xi = R_0 (1 + z)^{-1} \mathfrak{S}_k(\omega)$ (see McVittie 1965, p. 162) is called the "affine parameter" by Press and Gunn.

Gott and Gunn's original idea was that the gravitational-lens brightening of quasars by a nearby quasar (or a galaxy connected to it) acting as a lens, increases the chance of observing a distant faint quasar in the vicinity of a nearby quasar, and thus increases the probability of discovering close quasar pairs. Using Gott and Gunn's Figure 2 as a basis, the primary image is intensified by a factor of 2 (the galaxy operating as a compact lens), or perhaps by a factor of 4 (the galaxy operating as a distributed mass lens). In other words, Q_2 could now be 1.5 mag fainter; yet the spacing between Q_1 and Q_2 has been now reduced to 1″.25 from the observed 5″. While it is true that fainter quasars are more numerous, the chance of finding the companion at an apparent distance of 1″.25 is 16 times smaller than to find one at 5″ from Q_1.

As the numerous surveys of complete samples of quasars and quasar candidates (3C, 4C, Parkes) indicate, the number of quasars per unit apparent magnitude interval probably starts to drop beyond 18 mag, and most certainly beyond 19 mag, long before the plate limit of 21 mag is reached. From the histograms of these samples we can infer that the total gain in number, by including the objects between 19 and 20.5 mag, is at best 25–62 percent. Thus adopting Gott and Gunn's explanation, the probability of finding Q_2 is *lower* by a factor of $16/1.62 = 10$ than it was without the lens effect, when Q_2 has been a 19 mag bright object at a distance of 5″ from Q_1.

Gott and Gunn use the exponential relation $\log N(m_v) = \text{const.} + 0.6 m_v$ (or $= \text{const.} + 0.7 m_v$) to estimate the density enhancement of Q_2 in the vicinity of Q_1, due to the lens brightening of Q_2. Such exponential equations follow the histograms of complete samples only up to 19 mag. Thereafter the observed number of quasars per unit apparent magnitude interval is much lower than predicted by the equation. This discrepancy has been corroborated in the most recent Parkes $\pm 4°$ survey, in which more than 100 of the 341 sources in the equatorial belt were identified as quasars, with a positional accuracy ranging from 0″.5 to 2″.5.

[1] In the Introduction of their paper the authors mention that their explanation is an application in a different context of the gravitational lens brightening mechanism, originally proposed for quasars by Barnothy (1965). Gott and Gunn's second assumption renders the need for an intensification through gravitational lenses unnecessary. An explanation for the existence of double quasars, as well as for galaxy-quasar associations where the objects are not superluminous and the intensifying lenses are represented by globular clusters, was proposed by Barnothy (1974).

Yet, for the sake of argument, let us accept the greatest possible enhancement (by a factor of 7.2) in the density of companions around Q_1, as it was computed by Gott and Gunn. The chance of finding the companion at a distance of $1''.25$ would still be $16/7.2 = 2.2$ times lower than it was without the lens effect. The mistake in Gott and Gunn's reasoning is that they forgot to consider that when Q_1 acts as a lens on Q_2, Q_2 has to be closer to Q_1—that is, it has to be found within a much smaller area around Q_1 than before.

My conclusions follow:

a) A giant galaxy of 4 to $7 \times 10^{12} M_{\odot}$, invisible because of the brightness of a quasar at its center, could produce an optically resolvable "triple quasar" configuration. But the missing of the secondary image (its expected position correctly indicated on Gott and Gunn's Fig. 2) is a proof by itself, that in case of the double quasar 1548+115 the suggested gravitational lens effect cannot be involved.

b) Granted that the secondary image is for unknown reasons not visible, the solution offered for the problem to observe two quasars so close together is less probable than the original situation has been. Gott and Gunn's explanation would hence *aggravate*, not alleviate, the problem of 1548+115.

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