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# ARC MINUTE GRAVITATIONAL LENSES AND COSMIC STRINGS*

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In a recent letter by Paczynski,[1] it was suggested that several large separation gravitational lens candidates could be explained by the existence of cosmic strings. These lens candidates are quasar pairs with separation between 1 and 4 arc minutes. Paczynski states that arc minute separation quasar pairs, which are lensed by long straight strings, are a prediction of cosmic string theory. Paczynski's work received a great deal of attention when preliminary evidence for a gravitational lens with a $2.6'$ separation[2] was published by Turner *et. al.* Because a lens with such a large separation is difficult to explain with unseen conventional objects and requires a large mass to light ratio for the lens, this lens candidate was reported in some quarters[3] as evidence for a cosmic string. Subsequent observations now suggest that the quasar pair is not lensed.[4] The purpose of this correspondence is to point out that such large separation lens are *not* predicted by cosmic string theories.

The typical separation of the images of an object that is lensed by a cosmic string[5–7] is $4\pi G\mu$ where $G\mu$ is the dimensionless mass parameter of the string. A gravitational lens with a separation of $2.6'$ corresponds to $G\mu \approx 6 \times 10^{-5}$. While it is possible for a string configuration to produce gravitational lenses with image separations larger than $4\pi G\mu$ with favorable geometry, to increase the image separation by more than a factor of two or three above this value seems to require very unlikely conditions. While it was originally suggested[8–10] that a valve of $G\mu \sim 10^{-3}$–$10^{-5}$ might be useful for galaxy formation, further work has shown that these valves are in fact too high, and probably already excluded by observation. Arc-minute separation lenses are thus *not* a prediction of cosmic string theories. If some of these objects were lensed by long straight strings, it would *create* other cosmological problems, or suggest a basic misunderstanding of how cosmic string should behave.

We now list the evidence against valves of $G\mu$ greater than $10^{-5}$. Models where galaxies or clusters accrete around loops[11,12] have obtained $G\mu \sim 2\times10^{-6}$. Thus the *prediction* of cosmic string models is that $G\mu \sim 10^{-6}$ not $10^{-5}$. More serious problems for large values of $G\mu$ come from nucleosynthesis and anisotropy of the microwave background radiation. The most stringent limit on $G\mu$ comes from the requirement that the strings do produce so much gravitational radiation as to interfere with the successful primordial nucleosynthesis scenario.[13–15] This bound is stringent, $G\mu < 4 \times 10^{-6}$, but it can also be avoided by some types of cosmic strings that predominantly radiate massless goldstone bosons rather than gravitational waves.[16] However, these strings are not as attractive as seeds for galaxy formation, nor do they appear in any attractive particle physics models. A completely model independent limit has been obtained by Kaiser and Stebbins[17] who showed that $G\mu < 10^{-5}$ is required by the observed isotropy of the microwave background. Similar limits come from anisotropy due to string loops and the gravitational waves they produce.[18,19] While estimating the errors on these theoretical limits is difficult, we feel that at least the limit of Kaiser and Stebbins is actually conservative. As was stated in the paper the limit given is for a "minimal model" which, for example, does not include the increase in the r.m.s. temperature fluctuation due to the superposition of strings which will occur in any model. Thus, the limit $G\mu < 10^{-5}$ is quite firm, so the predicted separation of images lensed by a cosmic string is definitely *less* than one arc minute.

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