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# Microlensing In The TwQSO Mirage

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**Abstract:** The microlensing residual found in the TwQSO gravitational mirage shows unexpected structure on time scales much shorter than predicted. In addition to the predicted drift having a 30 year time scale, we find evidence for periodicity at periods of and around 1 year. These probably originate in orbital motion of the earth and binary motion of the microlensing star or stars. We also find a cuspy residual which has a time scale of weeks and probably originates in Jupiter mass objects in the halo of our Galaxy.

Gravitational microlensing was originally defined to be the result of a magnification in the image structure of a distant object, here a quasar, resulting from a gravitational mass along the line of sight but not local to the quasar source itself. Calculations (Refsdal, 1970) to show that microlensing could result in observable brightness changes and presently unobservable changes in image structure preceded the discovery of the first gravitational mirage, Q0956+561 A,B (the TwQSO), and the first models of the TwQSO system by Young et al (1981) included calculations of the expected microlensing (Young 1981). These models suggested that microlensing effects should be seen as systematic drifts in brightness of the microlensed B image from the A image with a time scale of about 30 years. The published curves showing this effect by Vanderriest et al (1989) and by Schild and Smith (1991) disagree somewhat because of systematic errors in the Vanderriest et al data.

Because Schild and Smith (1991) found fine structure in the microlensing residual in addition to the broad 30 year drift, a program of nightly monitoring has been underway at the 1.2m telescope of the Whipple Observatory on Mt Hopkins. Analysis of the full TwQSO data set now comprising 700 nights of data confirms the existence of fine structure as illustrated in Figure 1. The difference between the A and B brightness curves is shown for a time delay of 405 days, as given by Thomson and Schild (1993), but we find that the features do not appreciably change for any plausible value of the time delay. In addition to the slow 30 year drift, which we fit with a cubic equation, we find a cuspy residual with many peaks of up to 60 days full width, and suggestions of periodic components with periods of about a year. Fitting of periodic components and subtracting them off leaves a cuspy residual which we attribute to Jupiters or other massive objects with high mass-to-light ratio in the halo of our Galaxy.

We show a Fourier power spectrum of the microlensing in Figure 2. In this plot, with power shown as magnitude**2 as a function of frequency expressed in cycles per year, we find several unexpected peaks. The structure at 1 cy/yr might seem suspiciously like an artifact of the observing, but we believe that it is real and originates in the orbital motion of the earth. The peaks at periods of a few years we attribute to orbital motions of binary microlensing stars in galaxy G1.

The presumed origin of the periodic term in the microlensing is shown in Figure 3. We note

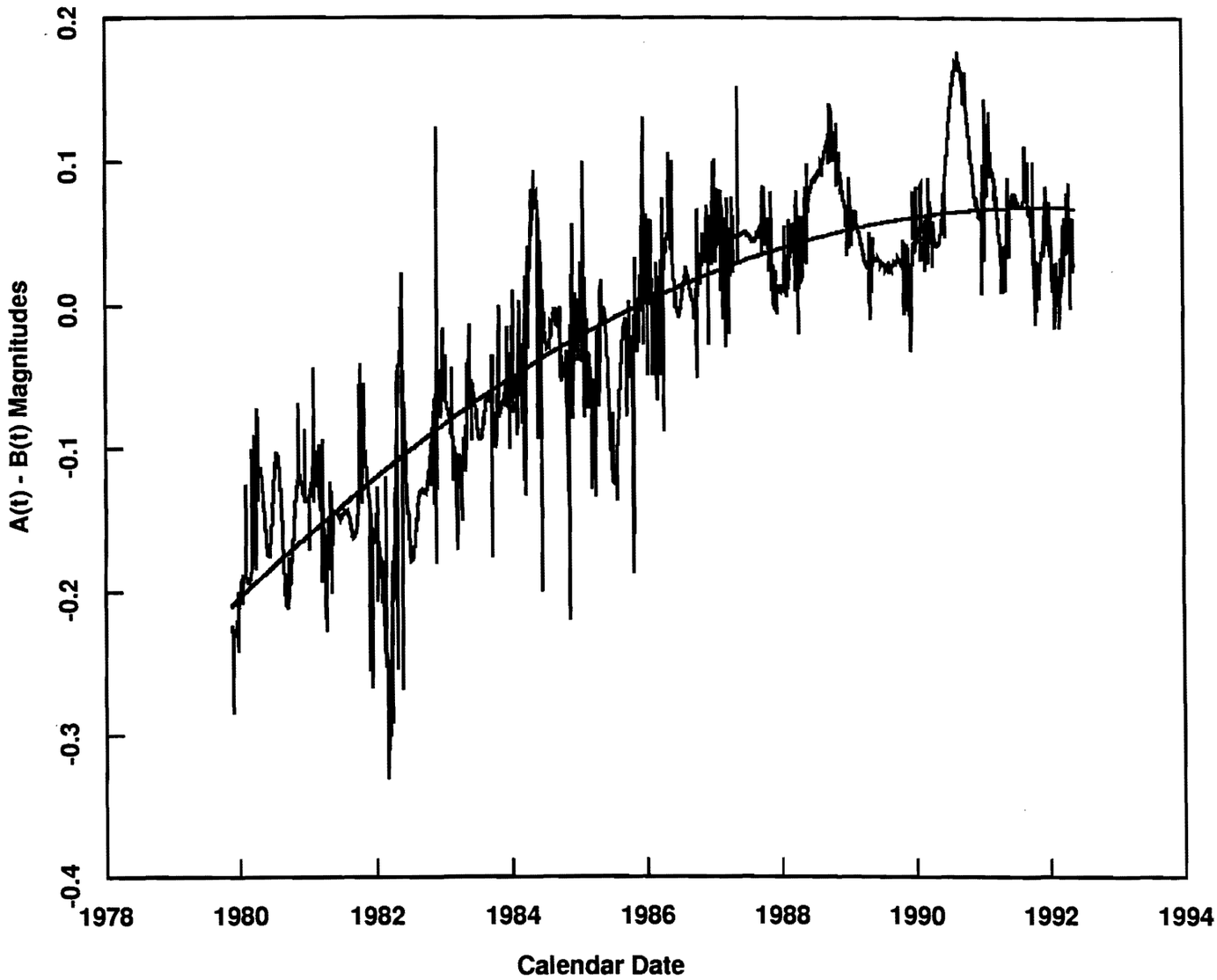


Figure 1: The microlensing residual, plotted for a time delay of 405 days, although the peaky residual remains for any plausible time delay. The overall trend has been fitted by a cubic polynomial, which is then subtracted before the Fourier analysis illustrated in Figure 2 is performed.

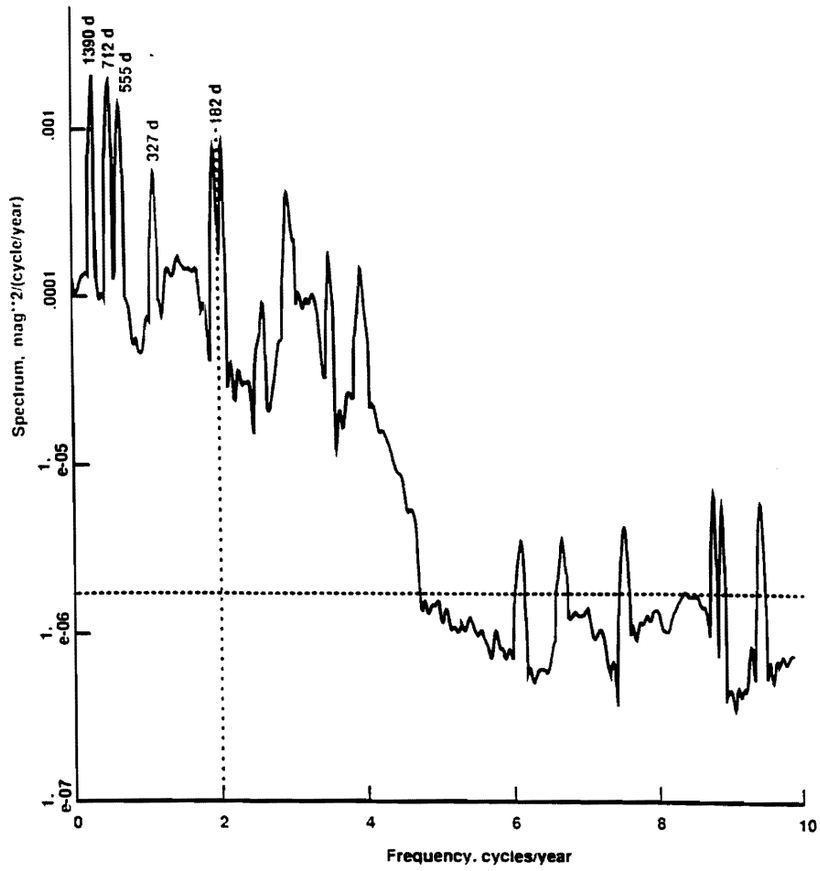


Figure 2: The Fourier power spectrum of the microlensing residual of Figure 1. Power is plotted as mag**2 as a function of frequency, expressed in cycles per year. Notice the logarithmic scaling of power, so the peaks are larger than apparent from the plot. Four discrete frequencies are found and labeled, including the earth's orbital frequency. A few higher frequency peaks may also be real.

that all the features in the plot, particularly the radius of earth's orbit, the orbital radius of a presumed microlensing binary with a period of a few years, and the size of a QSO black hole and accretion disc, are comparable to an astronomical unit. Therefore orbital motions of the earth or of the microlensing binary stars in galaxy G1 should project onto regions of the QSO accretion disc with large brightness gradients, and the orbital motions might plausibly be seen in the brightness curves. Of course the center of mass of the presumed microlensing binary traces a simple linear trajectory across the QSO source, and the periodic brightness changes, observed to be a few percent, are just a secondary effect.

An irregular and rapid component is also found in the microlensing. It produces cusp-like profiles with a time scale of weeks. The cusps are not separated, but appear to merge with one another much as the calculations of Wambsganss et al (1990) predict for a high surface mass density. Because of the short time scale they presumably originate in the halo of our own galaxy, although other explanations in terms of quasar structure and very rapid changes of caustic structure are being explored. They are of course produced in the direction of a lensed and microlensed QSO image, so even low mass particles can produce a substantial effect; we estimate the masses to be about a hundredth of a solar mass. Unless they are unique to our galaxy, they must have a very high mass-to-light ratio, exceeding 1000, and they are probably the MACHOS of some fashionable current literature (Alcock et al 1992).

The existence of this irregualr cuspy background explains in part why it has been so difficult to accurately determine the TwQSO time delay. In any modern data set there are at least 100

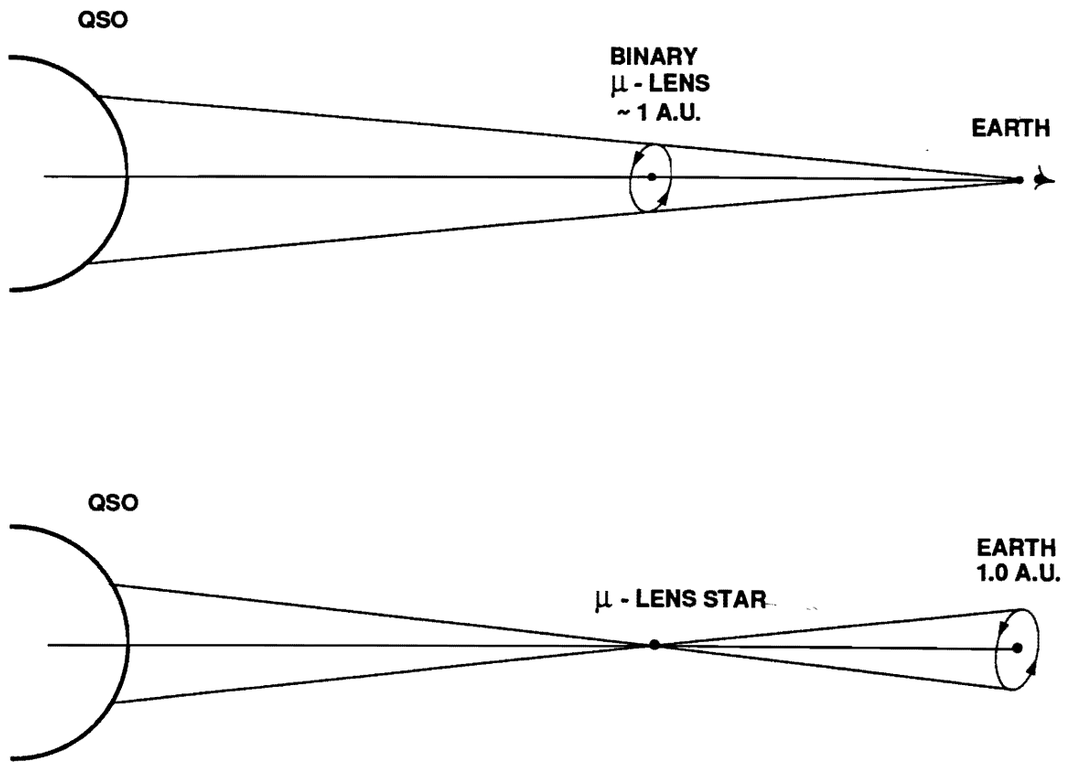


Figure 3: A schematic illustration to suggest the origin of the observed microlensing periodicities. The top illustration calls attention to the fact that a binary microlensing star in lens galaxy G1 would have orbital motion of about 1 a.u. amplitude at G1, or only a few a.u. projected back onto the QSO accretion disc. The lower illustration reminds us that even a single microlensing star would reflect the earth's orbital motion with an amplitude of a few a.u. on the accretion disc. These moving source regions would be expected to cross regions with large brightness gradients at the QSO accretion disc, and might plausibly be observable.

overlapping data points for any plausible time delay test value in an autocorrelation calculation, and yet all such calculations show only a broad minimum with a width of 100 days or more (Thomson and Schild 1993). Thus with so much data presently available, although it should be possible to specify the time delay to a fraction of a day, the errors are still a week or two and we attribute this to the complication that both image components are affected by this cuspy residual, which has an amplitude of several percent.

# References


Alcock, C. et al,: 1992, in *Gravitational Lenses*, ed R. Kayser, T. Schramm, and L. Niser,: p. 156

Refsdal,: S. 1970, *Ap J* **159**, 357

Schild, R. and Smith, R. C.: 1991, *A J* **101**, 813

Thomson, D. J. and Schild, R.: *Ap J Letters*, in preparation

Vanderriest, C., Schneider, J., Herpe, G., Chevreton, M., Moles, M., and Wlerick, G.: 1989, *A&A* **215**, 1

Wambsganss, J., Pacynski, B., and Schneider, P.: 1990, *Ap J (Letters)* **358**, L33

Young, P., Gunn, J., Kristian, J., Oke, J., and Westphal, J.: 1981,*Ap J* **244**, 736

Young, P.: 1981, *Ap J* **244**, 756