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BLACK HOLE OR MECO? DECIDED BY A THIN LUMINOUS RING
STRUCTURE DEEP WITHIN QUASAR Q0957+561

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ABSTRACT

Optical, Infrared, X-ray, and radio wavelength studies of quasars are beginning to define the luminous quasar structure from techniques of reverberation and microlensing. An important result is that the inner quasar structure of the first identified gravitational lens, Q0957+561 A,B seems not to show the kind of structure expected for a super-massive black hole, but instead show a clean-swept interior region due to the action of an intrinsic magnetic propeller, just as expected for a MECO (Magnetic Eternally Collapsing Object) structure. Given the present state of the observations, the strongest model discriminator seems to be the existence of a thin luminous band around the inner edge of the accretion disc, at a distant radius $\sim 70 R_g$ from the $M \sim 4 \times 10^9 M_\odot$ central object. Since the existence of a clean magnetic propeller swept inner region $\sim 70 R_g$ surrounded by a sharp $\sim 1 R_g$ disc edge are the low-hard state spectral properties associated with a highly red shifted central MECO object, we are led to the conclusion that these observations imply that the Q0957 quasar contains a central super-massive MECO instead of a black hole. In this report we review the details of the observations which have compelled us to reach this conclusion.

1. Introduction

In this paper we present observational and theoretical arguments that black holes, as the active ingredient in quasars seen at large cosmological distances, may have outlived their usefulness. Black holes were first conceived as possible sites of extreme physics, but interest in them grew during the 1960's era when quasars were discovered and understood to be at such large cosmological distances that they could not be understood as stars. So black holes were invoked to explain how such a prodigious quantity of energy, equivalent to the combined light of a billion ordinary stars, could originate in such a small object.

As a long literature about quasar properties unfolded, problematic difficulties with the black hole objects were encountered because of the complexities associated with their event horizons. As the theory is presently understood, the event horizon in a black hole represents a surface inside of which nothing, even light, can escape the essentially infinite gravitational force which would be measured by a local observer. Hence observers inside of the event horizon cannot communicate with observers outside of the event horizon by the use of light signals. However this represents a violation of the Strong Principle of Equivalence, which states that Special Relativity must hold locally for all local observers at all spacetime points in the universe. Thus black holes have always been in violation of the Strong Principle of Equivalence in General Relativity, and for this reason a new understanding of the physics involved is required.

Rarely mentioned is another seeming contradiction; if black holes are the place where

light cannot escape to the rest of the universe, how does it happen that they are the most luminous objects in the universe? The currently accepted answer is that the luminosity originates in an accretion disc around the black hole. However this picture fails because a "standard black hole model" of quasars which can explain spectral states involving radio loud and radio quiet emission cannot be found. Instead, patchwork additions to the black hole theory need to be added in an ad hoc manner as surprising observations of radio, X-ray, and outer "dusty torus" structures accumulate. For this reason the standard black hole picture of quasars is very limited in its predictive power.

In spite of these difficulties, black holes were consistently invoked in all discussions of quasars since the discovery in 1964 (Schmidt, 1965). Today, practically any theoretician will say with certainty that the objects at the centers of galaxies are black holes, and will also say that black hole theory is reasonably well understood.

But this ignores the fact that two new key observations were not at all anticipated or predicted by this standard black hole theory.

The first unexpected observation by Robert Antonucci (1993) showed that the quasar objects must be surrounded by a "dusty torus" region whose elliptical contoured surface guides the Elvis outflow wind structure. The theory community responded by cobbling up an ad hoc theory for the dusty torus, which has not survived modern scrutiny. A recent study of UV-optical continuum reverberations by Lovegrove et al showed that all 55 of the radio quiet quasars studied show evidence of this structure, establishing that it is a universal property of quasars not predicted theoretically.

A second discovery will be the subject of this report. The standard black hole theory predicts that an accretion disc penetrates to the inner region at 6 gravitational radii, or perhaps a bit less. Since a black hole has no hair, meaning that no magnetic field can penetrate its event horizon, there cannot be a centrally anchored dipole magnetic field in

the innermost region. But direct observation of reverberation of the optical light from the center of quasar Q0957 shows that the inner region is surprisingly swept clear, as if by a strong rotating magnetic field from its central supermassive compact object. Furthermore, the inner accretion disc edge has the apparent structure of a hot ring, again suggesting that a strong centrally located magnetic field is abrading the inner accretion disc edge and strongly heating it. The existence of such a centrally located magnetic propeller effect inside of the accretion disc strongly contradicts the standard black hole theory.

The existence of such a hot ring where none was expected has already been reported by Schild et al (2006, hereafter SLR06). However that report brought in many reverberation and microlensing observations of many kinds that were most often collected to study the time delay measured for calculation of the Hubble constant, or the nature of the baryonic dark matter. So many key observations are presently scattered in an unfocused literature already published. To fortify the conclusion based on these results, we present in this report a summarized compendium of the results of published investigations in order to make a comparison of relevant observations to competing theoretical models.

Recall that the Q0957+561 A,B quasar lens system, the first discovered multiple image gravitational lens system (Walsh, Carswell, and Weymann, 1979), was heavily observed in the two decades since its discovery with the expectation that measurement of its time delay would allow determination of the Hubble constant by the Refsdal (1964) method, independent of the classical methods based upon Cepheids. With the discovery of the time delay by Schild and Cholfin (1986) an unexpected rapid microlensing was found (Schild 1996), and since the baryonic dark matter implications eclipsed the time delay and Hubble constant program, a long literature that followed (Schild 2004a, 2004b, 2007, Schild & Dekker, 2006) emphasized the rapid microlensing.

But the same measured brightness record had implications for the nature of the

luminous quasar structure as well. Already the first Q0957 rapid microlensing report by Schild (1996) concluded that the quasar must be larger than previously believed, and ”dominated by rings or shells.” A double-ring model simulation by Schild and Vakulik (2003) showed that the amplitudes and the durations of the observed microlensing brightness fluctuations on long and short time scales could be understood to be compatible with reverberation and autocorrelation measurements.

The structure of this paper is as follows. In sections 2-5 we discuss the basic statistics defining the accuracy of the data, followed by a detailed discussion about the reverberation data used to infer the location of the Elvis outer outflow wind structure, and the signature of a sharp ring at the inner edge of the accretion disc. Then in sections 6 and 7 we conclude by showing that, instead of a black hole driven structure, the observational results for Q0957 favor structure dominated by a central dipole field of a MECO object in a low-hard state. In an appendix we show how an additional contradiction of standard black hole physics related to space connectivity for the completeness of quantum fields, can be resolved if MECO instead of black holes are the central compact objects in quasars

2. The Q0957 Brightness Monitoring Data Quality and Quantity

We begin with a discussion about the quality of brightness monitoring data. The analyzed data table, available online at <http://www.cfa.harvard.edu/~rschild/fulldata2.txt> reduces all data taken on an individual calendar night and averages the data together, and assigns an observation time from the mean for the individual observations. Data are almost always averages of 4 CCD image frames analyzed for brightness separately. This usually gives 4 nightly brightness estimates, which usually have a 1-sigma rms near .01 mag, or 1% brightness error for the nightly mean. Independent confirmation of this estimate was made by statistician David J. Thomson, who estimates nightly average errors of 0.006 and 0.008

mag for the A and B images, respectively (Schild and Thomson, 1995). A comprehensive analysis of the statistics of the data set focused on the time delay controversy is given in Thomson and Schild (1997).

Figure 1 is a plot showing the number of nights where there is data overlap between images A and B after correction for cosmological time delay. This includes interpolations of up to 2 days, meaning suppose one makes an observation on Jan 1 2000. Then does one have an observation for Jan 1 + 417 days in 2001, with the possibility that on Jan 1 + 417 days one actually made the observation on that date, or could interpolate to that date with at most a 2-day interpolation window? This makes sense, where our sampling rate is 1 day so the Nyquist frequency is 2 days. We can still expect that the data point compared to image A on Jan 1 2000 will have a magnitude estimate accurate at the 1% level for 417 days later, after the Q0957 brightness record structure function given by Colley and Schild (2000).

Thus Figure 1 shows how many dates for image A observation will have a 1 % accurate image B brightness estimate. When this plot was made in Jan 1993, for any date of observation of image A there would be several hundred 1% quality measurements for image B made 417 days later. We are interested in lags in this plot of less than 10 nights. The Fig. 1 plot shows that by 1993, at least 270 data points define brightness for lags up to 10 days from the cosmological 417 days lag.

This means that when one compares the measured brightness of image A with brightness of image B, 417 +/- 10 days later, that brightness is estimated with high accuracy. Over 200 points overlap. Therefore we may conclude that we know very well the brightness properties of the two images for lags near the cosmological lag, 417.1 days (Colley et al, 2003).

The quality of the data, usually expressed as a 1σ error, has been commented upon

repeatedly. Thus Schild and Thomson (1995) reported a median error of 0.006 magnitudes for both images, and Schild and Thomson (1997) reported mean error estimates of (.00954, .01202) for images (A,B). And when Colley and Schild (2000) compared their refined magnitude estimates with the long Schild et al record, they found mean rms differences of only (.006, .008) magnitudes for images (A,B). Because the quasar shows nightly brightness fluctuations of approximately 1%, and larger trends on longer time scales, these trends are well measured with available photometry. The observed nightly brightness fluctuations for Q0957 have been expressed as a structure function by Colley and Schild (2000) and as a wavelet amplitude by Schild (1999). Hence on the basis of the above analysis it is safe to conclude that both the quality and the quantity of quasar brightness data are sufficient to allow meaningful analysis of the quasar’s internal structure to be made.

3. Outer Quasar Structure Seen in Autocorrelation and Simple Inspection

The Figure 2 auto-covariance (auto-correlation) plot is expected to show correlation on time scales related to the outer Elvis structures, around 100 proper days, and structure related to the inner edge of the accretion disc. In Fig. 2, which was originally shown at the 1993 Padua Symposium (Thomson and Schild, 1997) the auto-correlation for the A (dashed) and B (solid line) images are shown together. Multiple peaks for time lags near 100 proper days are presumed to result from a disturbance taking place at the inner region of the quasar, near the inner edge of the accretion disc, and then with reflections or fluoresces off the Elvis outflow structures which are expected near to but just within the light cylinder radius (Schild and Vakulik, 2003; SLR06, SLR08). Because microlensing is expected to cause complications in the detection of these outer reflections, the B image with its higher microlensing optical depth should show different autocorrelation than A. Thus we have included a schematic ”bottom” or ”continuum” level in figure 2 for the two quasar

images. This emphasizes how similar the peaks measured for the two lensed images are in amplitude and width. Since microlensing can locally amplify random parts of the quasar structure, we consider as significant only peaks found in the autocorrelation estimates of both images.

The images arising in the lowest-lag Elvis structure, at 129 and 190 days (observer's clock), have about the same width, about 50 days, and half again larger widths of 75 days, for 540 and 620 day lag peaks. The 620 day lag peak is not convincing, by itself, and call it unobserved if you like, but if somebody insists that it must be there, one could argue that it is.

A similar pattern of quasar optical reverberations are now recognized by direct inspection of the measured brightness curves in a second lensed quasar system, the Einstein Cross (Q2237), with excellent quality data (Wozniak et al 2000) available at:

<http://www.astro.uw.edu.pl/ogle/ogle3/huchra.html>

In examining the above website the reader is encouraged to scroll down to see the plot of optical brightness monitoring for the 4 lensed images. The pattern of brightness peaks to be seen are similar in amplitude and duration to similar peaks found in Q0957. The Einstein Cross peaks I refer to are best seen in the upper green plot for image A, and the peaks occurred at $(\text{HJD} - 24400000) = 2500, 2950, \text{ and } 3300$, with possibly more, but microlensing makes interpretation insecure. The peaks have a brightness amplitude of approximately 0.2 magnitudes and durations of approximately 50 days. The peaks have been discussed in the context of quasar structure by SLR08. These peaks were used by Vakulik et al (2006) to determine the time delays of the quasar images.

Comparison of the Q2237 direct brightness curves shows that reverberation of a central quasar disturbance reflects off the outer quasar structure at lags and time durations about

as inferred from the Q0957 autocorrelation estimates. We find that for both quasars, outer structure gives reverberation estimates of size at observed scales near 200 days and observed widths near 75 days; with $(1+z)$ cosmological time dilation correction, these become proper (intrinsic) reverberation delays near 100 days and widths near 25 days.

Of more interest is the question of whether structure is evident on scales comparable to the expected structure at the inner edge of the accretion disk, at $6R_G$. This size scale would correspond to elapsed times of less than a day on the observer’s clock. Moreover, in typical autocorrelation estimates, any significant noise contribution should decrease calculated correlation away from 0 lag; detection noise and cosmic dispersion cause longer lags to give strongly decreasing correlation. But here, the curves are quite different; the Q0957 inner structure has the character of wide peaks of approximately 10 days, with additional sub-peaks at 15 days (A image) and 5 days (B image). This means that for these short lags the data are correlated, and insofar as the quasar is bright today it will probably also be bright for 10 days or so. In other words, an inner structure is in evidence, and insofar as the autocorrelation peak reflects internal structure limited by causality at light propagation speed, a structure size scale is implied. Since an inner scale of 1 light day for the inner accretion disc edge is expected but not observed, and since instead a broad inner plateau is found, we conclude that the inner Q0957 quasar structure is not at the location of the innermost stable orbit (or that quasar brightening effects propagate much slower than light speed). A further discussion of the nature of this reverberation plot allowed Schild (2005) to infer the quasar orientation with respect to the plane of the sky. Even more importantly, SLR06 showed how this data implied the existence of a bright narrow band at the inner edge of the accretion disc, which was required to explain the extremely rapid 5-hour brightness fluctuations that were seen in the microlensing data.

We present in Fig. 3 a more recent cross-correlation calculation with finer output

scaling that shows better the results for 10-day lags, which relate more to the central quasar structure. This calculation from 1995, with half again as much data, is for A image alone. The peaks from the outer Elvis structures at 129 days and 190 days are strong. Their widths are comparable, about 45 days, which is twice the width of the peak around 0 lag, suggesting that the widths are dominated by the light scattering or fluorescence from the Elvis structures, which have larger dimensions, as estimated in SLR06.

It is now extremely significant that the auto-correlation has strong structure between 0 and 25 day lags. Recall that for noise-dominated data the data point for 0 lag should be highest and the autocorrelation function should rapidly decline for lags of 1, 2, 3, ... 10 days. But the plot shows sub-peaks around 6, 11, and 20 days, within a broad general peak of about 25 days width. This probably is the result of the Q0957 quasar's innermost structure.

Figure 4 shows similar data for the B image. It gives similar results for the 129 and 190 day peaks, understood to be related to the outer Elvis structures. The heights and widths are similar for the Elvis peak lags at 129 and 190 days seen in image A (Fig. 3).

And the inner peak again has a width of about 25 days, with again substructure peaks at 5 and 20 days. The fact that these inner sub-peaks do not exactly agree probably has to do with microlensing, (which originates in the random star field in the lens galaxy), of this inner structure.

Combining results from Figures 3 and 4 showing autocorrelation estimates from 1995, we have the suggestion of structure on time scales of 6, 11, and 20 days and an overall size limit for the inner quasar structure of approximately 25 light days (observed).

4. Results from Cross-correlation analysis

The above two plots have been about autocorrelation. Now we wish to discuss the previously published plots for CROSS-correlation.

First you must ask yourself, with many hundreds of data points of 1% quality and with observed nightly brightness fluctuations at least 1% between observations, isn't it obvious that for some cosmological time delay, say for example, 417 days, there will be a very large spike in the cross-correlation curve? With excellent data sampling, characterised by hundreds of data points at resolution of 1 day and with detection noise at or below the amplitude of quasar brightness fluctuations, this large spike should have a width of 1 or 2 days.

But this cross-correlation spike has never been found by any of the 10 research groups that have sought it.

Thus we immediately are confronted with the fact that probably the inner quasar structure is softening the expected cross-correlation peak. Fig. 5 is a cross-correlation plot to illustrate this. It was already published as Fig. 2 in Schild and Thomson (1997). Instead of a large spike with a 1-day half-width, we find a broad cross-correlation peak with a 50 day half width. The broad peak is punctuated by sub-peaks as already noticed by Schild and Thomson, who comment that the cross-correlation sub-peaks "... tend to have a uniform spacing of 16 days, which may correspond to an internal reflection within the inner quasar structure."

Everybody agrees that the central object must be illuminating the inner edge of the accretion disc, and that since we are dealing with high luminosity quasars one should use the Shakura-Sunyaev (1973) thin accretion disc model. For the case of a central black hole in Q0957, this would be at a radius less than or equal to $6R_G$, which is less than a light

day for either quasar system, even with cosmological $(1+z)$ correction to the observer’s clock. The fact that a luminosity associated with the inner edge of the accretion disc is not observed in cross-correlation, or autocorrelation, or microlensing for Q0957 means that there is nothing there. What is seen instead is the structure in the autocorrelation plot with sub-peaks around the 417-day peak of the overall autocorrelation curve, Fig. 5.

These sub-peaks are always around 10 days away from the cosmological time delay, 417 days, and so they are easily understood as the bright inner edge of the accretion disc that everybody agrees must exist. But this makes the inner quasar structure approximately 10 times larger than expected. With elaborate corrections for the inclination of the object, SLR06 found the luminous accretion disc inner edge to have a radius $\sim 70R_G$ in Q0957, instead of the $\sim 6R_G$ expected for a black hole. The sub-peaks in the Fig. 5 autocorrelation plot are around 379, 392, 408, 417, 420, and 425 days.

These cross-correlation experiments have long shown an interesting effect, namely that the cosmological time delay measured for this data has been changing with time. This was discovered in Thomson & Schild (1997) where contours of the cross-correlation time delay as a function of observation date are shown. It may be seen that the time delay peak was shortening with calendar date. This may be understood as a result of the magnification cusp of a microlensing star passing across the face of this quasar, and highlighting the internal structure progressively.

Thus from many points of view we infer that if there is any luminosity within $70R_g$ we will have seen it selectively amplified at some time. Instead, we just seem to see those $70R_g$ structures being selectively amplified at time scales near 10 days. Moreover, hypothetical structure at $6R_G$ orbiting at the inner edge of the accretion disc, would be expected to create strongly periodic brightness fluctuations, not observed. On the basis of these observations it was concluded in SLR06 that an intrinsic magnetic propeller contained within the central

compact object of Q0957 had cleared out the inner region of the accretion disc. This was found to be consistent with the MECO model while being inconsistent with inner structure at $6R_G$ inferred for a standard black hole model. The existence of internal structure is probably part of the reason why seemingly reliable calculations do not consistently indicate the same time delay even for data sets considered reliable by Oscoz et al (2001).

The published SLR06 report contains an explanation for the cross-correlation peaks at the particular values around 392, 404, 424 days found, for the already determined inclination of the quasar and inner structure at a radius $\sim 70R_G$. The discussion in Section 2 of SLR06, which we do not repeat here, shows that inner luminous ring structure produces cross-correlation at a variety of lags as observed, since the nearest and farthest surfaces would both produce strong reflection.

Also discussed in SLR06 is the location of the radio emitting region. As demonstrated there, reverberation of the compact core radio emission has been found to be 30 days (observer’s clock, UV-optical leading radio) and a series of microlensing events of the radio emission allow the size and fraction of the compact radio source emission to be determined from the duration and radio brightness amplitude of the events.

5. The Implications of Rapid Quasar Microlensing

The preceding sections have detailed why we believe that evidence exists for quasar luminous continuum structure on size scales of the outer Elvis structure, 50 proper light days, and for an inner structure $\sim 70R_g$. But another observation shows an important characteristic of the inner structure.

In Fig. 6, which is a repeat of Colley and Schild (2003), we show a simple plot of the quasar brightness measured unusually carefully for the duration of the night, in 1995.9

and again 417 days later. In this plot, brightness measured for the first arriving A image is plotted as open circles, with a single data point and error bar plotted for the hourly averaged brightness. It may be seen that nightly brightness trends with typical amplitudes of .01 magnitude were found for the A image.

The brightness of the B image at the same quasar time, measured at Earth 417.1 days later and plotted as filled circles, shows evidence for the same pattern of brightness trends. Thus on JD-2449701.9 the A image underwent a 0.01 magnitude fading and the B image recorded 417 days later shows that the A fading was a continuation of a quasar fading trend that had begun several hours earlier. Similar trends observed on the 3 following nights provide simple evidence that the quasar has intrinsic brightness drifts with amplitude 0.02 magnitudes on time scales of 12 hours, that are being recorded with reasonable accuracy and seen at Earth with the 417.1 day cosmological time delay lag. And that the 417.1 day time delay found from a continuous monitoring campaign reported in Colley et al (2003) must be correct for this data sample.

Now we remark on the events recorded on JD - 2449706, where image A had a deep (2%) minimum and image B, observed 417 days later, had a shallow minimum. The difference between the two brightness trends must have been caused by microlensing. A more convincing plot of this observed event is shown as Fig. 2 in Colley and Schild (2003). This simple observation of a 1% microlensing brightness change in 5 hours proper time challenges theory on two points; it is not understood in the black hole model how the quasar can change brightness due to intrinsic quasar fluctuation processes for quoted accretion disc sizes, or how microlensing can change so quickly for the quoted quasar luminous accretion disc sizes. And for microlensing to occur on such short time scales, a fine structure in the microlensing caustic pattern due to a graininess of the mass distribution in the lens galaxy from planet mass microlenses must be present. Comparable fluctuations have been

simulated by Schild and Valukik (2003) with equal positive and negative sub-cusps on day time scales only if planet-mass microlenses dominate the mass of the lens galaxy.

We emphasize that the rapid microlensing event requires two physical effects not expected in astronomy; the quasar must have fine structure, and the mass distribution within the lens galaxy must be dominated by planetary mass bodies. Direct simulations of the Q2237 microlensing by Vakulik et al (2007) also conclude that the microlensing must be caused by Jupiter mass, $10^{-3}M_{\odot}$, compact objects.

Standard arguments of causality require that the existence of observed fluctuations intrinsic to the quasar imply structure on scales of 12 light hours, which after correction for cosmological $(1+z)$ time dilation corresponds to a size scale of less than $1R_g$. With the spherical or cylindrical geometry assumed for the quasar central source, this implies the existence of a ring structure dimension of such size, and we have interpreted this as the radial thickness of the accretion disc inner edge, since that would be the smallest dimension associated with an accretion disc model. Thus the rapid fluctuations seen convincingly in Fig. 6 and found previously in the data and structure function, Figs. 3 and 5, of Colley & Schild (2000) probably imply the existence of quasar structure with significant luminosity on a small spatial scale of $1R_G$.

Further analysis in section 2 of SLR06 amplifies this result, with the additional conclusion that the linear increase in the wavelet amplitude with lag found by Schild (1999) is also compatible with a ring structure for the central emitting region.

6. Summary and Model Comparison

The purpose of this section is to summarize the results from each preceding section, and to comment upon the relevance to the fundamental issue, which is whether these first

results of the direct detection of UV-optical and radio inner quasar structure favor a black hole or MECO interpretation.

In section 2, we considered the quantity and quality of data that contribute to the conclusion that Q0957 does not have accretion disc structure expected at approximately $6R_G$ (somewhat smaller for rapid rotation of the central object). We showed that hundreds of data points define the autocorrelation and cross-correlation estimates of structured quasar brightness trends, and their 1 % accuracy was emphasized.

In section 3 we emphasized that autocorrelation estimates for long lags, up to 2 years, showed structure that suggested that any disturbance seen first in the central region reverberates in outer structure that has size scales attributed previously to the Elvis outflow structures. Originally discovered in Thomson and Schild (1997) these structures now are interpreted to reveal the details of the quasar’s central structure and orientation in space (Schild 2005).

We also found in section 3 that autocorrelation plots revealed the presence of UV-optical luminous inner structure not at the location of the innermost stable orbit (less than or on the order of $6R_G$) but rather at a much larger radius on the order of $70R_G$. This observation, consistent with the intrinsic magnetic propeller model associated with the MECO theory for quasar structure (SLR06), is not that which is expected from black hole quasar structure models. Figures 3 and 4 seem to indicate the existence of inner structure, and the width of the central autocorrelation peak (25 days, observed) is interpreted as a determination of the structure’s central radius in light days.

In section 4 we recalled that many cross-correlation calculations have sought a sharp peak for the cosmological time delay, but it has not been found for any of the long brightness time-series records available. This is most easily understood as the result of the internal structure and its significant microlensing, and evidence for this interpretation

is probably seen in the fine structure of the cross-correlation estimates. The evident cross-correlation fine structure is arguably on the time scale of the inner structure evident in the auto-correlation plots, Figs 3 and 4, with evident structure at lags 10 - 20 days.

In section 5 we examined the evidence for a rapid microlensing that is seen to 99.9% significance in data obtained in two separate observing seasons. The generally good agreement of the data from the two seasons within the quoted error bars for overlapping data points provides confirmation that the brightness estimates and adopted time delay are correct. And the existence of such rapid microlensing requires the existence of sharp quasar structure that is incompatible with black hole physics and was not predicted before it was observationally discovered.

With these key observational results in mind, we discuss the comparison of standard black hole models to MECO model results. Although a general relativistic 3-dimensional simulation of a MECO object has not yet been undertaken, an analytical model has been created by Robertson and Leiter (2002, 2003, 2004, 2005) and is the basis for these conclusions.

Based on the analysis of the observational evidence presented in this paper it has been shown in SLR06 that Q0957+561 has the four intrinsic structural elements as follows:

- 1. Elliptical Elvis Structure located at distance R_e from the central object and height H_e above the accretion disc plane: $R_e = 2 \times 10^{17}\text{cm}$ ($320 R_G$, 77 light days), $H_e = 5 \times 10^{16}\text{cm}$ ($80 R_G$, 19 light days).
- 2. Inner Radius of Accretion Disk: $R_{disk} = 4 \times 10^{16}\text{cm} = 64R_G = 15$ light days.
- 3. Hot Inner Accretion Disk Annulus: $\Delta(R) = 5.4 \times 10^{14}\text{cm} = 1 R_G = 5$ light hours.
- 4. Base of Radio Jet: $R_{rad} = 2 \times 10^{16}\text{cm}$ (8 light days), $H_{rad} = 9 \times 10^{16}\text{cm}$ (35 light days).

days).

A cartoon illustrating a cross-section of this quasar structure model has been given as Fig. 1 in SLR06. Attempts to explain all four components of the observed inner structure of the quasar Q0957 in terms of standard central black hole models have failed for the following reasons:

a) Modeling them in terms of an intrinsic magnetic moment generated by a central spinning charged black hole fails because the necessary charge on the spinning black hole required would not be stable enough to account for the long lifetime of the inner quasar structure.

b) Modeling them in terms of a Kerr black hole ADAF accretion- disk-coronajet (Narayan & Quataert 2005; McKinney & Narayan 2007) in which the magnetic field is intrinsic to the accretion disk and not intrinsic to the central rotating black hole, fails because it cannot account for the very large opening angles for the coronal Elvis outflows, and in particular it cannot account for the hot thin inner disk annulus that is observed

c) Modeling them in terms of a Magnetically Arrested Disk (MAD) black hole (Igumenshev et al. 2003, Igumenshev, 2008) fails since it cannot account for the hot thin inner disk annulus that is observed within the inner structure of Q0957. Instead the MAD simulations show a broad band of material starting at $74 R_g$ and extending inward to about $64 R_g$ from which a stochastic injection of “magnetic islands” of low density plasma would occur. These plasma blobs would not be visible to the observer since they would have a much lower optical luminosity compared to that of the accretion disc. Hence instead of the observed truncated disc with a very narrow annular band of material of radial thickness on the order of $1 R_g$, the MAD model predicts a truncated disc with a broad irregular inner annular band of radial thickness on the order of $10 R_g$. Thus it follows that the MAD black hole model can be ruled out as an explanation of the inner structure observed in Q0957+561

because if a MAD black hole accretion disc had been operating, the clean fluctuation signal associated with the hot ring structure would not have been seen.

However it has been shown that all the four components of the observed inner structure in the quasar Q0957+561 can be consistently described within the context of the Magnetospheric Eternally Collapsing Object (MECO) model described in SLR06, in which a very strong intrinsic magnetic field anchored to a highly redshifted rotating central compact MECO interacts in a magnetic propeller mode with the surrounding accretion disk and generates all the four components of the Q0957 structure. Such MECO models are characterized by highly redshifted, Eddington-limited, collapsing central compact objects containing strong intrinsic magnetic fields aligned with their MECO axis of rotation.

The MECO contains a central rotating magnetic object whose dynamo sweeps clean the central region of the quasar out to a distance at which the magnetic propeller acts on the inner edge of the accretion disk, and a radio-emitting region above the disk where magnetic field lines must twist and bunch up until they eventually break and reconnect at relativistic speeds. Such an object does not have an event horizon; instead, infalling material collects at an inner structure just beyond $2R_g$ that further collapses to higher redshift while remaining in causal connection for all time. Because of the small light cone angle for radiation escaping from this highly redshifted region to the distant observer, the resulting low luminosity in the far-infrared wavelengths makes this region difficult to detect.

In the MECO model for Q0957, the magnetic propeller interacts with the inner regions of the accretion disk and creates a very thin hot inner annular (band-like) structure and an outer coronal structure characterized by strong relativistic outflow with a wide opening angle to the z-axis of rotation as is observed. In addition the size and location of the radio-emitting region associated with the structure in the quasar Q0957+561 have been found to correspond to the region above the central compact object where the reconnection

of magnetic field lines at relativistic Alfvén speeds, like that generated by a rotating central MECO containing an intrinsic magnetic field, should occur. The structures found to dominate the UV-optical and radio emission are shown correctly scaled in Figure 7.

It is important to note that the MECO model that best fits the inner structure observed in the quasar Q0957+561 differs significantly from most black hole models currently under consideration. In particular, the observed structure they generate seems to resemble the complex inflow-outflow pattern seen in magnetic propeller models for young stellar objects. The action of such magnetic propeller forces on young stellar objects has been discussed and simulated by Romanova et al. (2002, 2003a, 2003b) with non-relativistic models that produce observable structures whose spatial geometry is very similar to the inferred Schild-Vakulik (2003) structure.

On the basis of the above arguments we come to the conclusion that observation of the four components of the stable non-standard inner structure within the quasar Q0957+561, and especially the existence of the hot thin inner disk annulus that is observed, represents strong evidence for the existence of an observable intrinsic magnetic moment, generated by a supermassive $3 - 4 \times 10^9 M_{\odot}$ MECO acting as the central compact object in this active galaxy, which implies that this quasar does not have an event horizon.

7. Concluding Remarks

We have shown that a comprehensive analysis of the gravitational lensing and microlensing observations of the quasar Q0957 indicates that the internal structure of this quasar appears to be dominated by a highly redshifted supermassive central compact object that contains an observable intrinsic magnetic moment and therefore cannot be described by a black hole. The implications of this startling discovery are so profound that it is

necessary to clarify and review the supporting observational evidence.

For the benefit of the astrophysics community, this paper has summarized within a single document the full list of unique gravitational microlensing and reverberation observations of quasar Q0957 which have permitted a detailed reconstruction of the intrinsic structures emitting radiation from its interior regions. Surprisingly these observations failed to reveal the expected accretion disk extending in close to the central object. Instead it was found that the inner accretion disk contained a large empty region which ended at a large radius where we found a thin hot inner ring. In addition, it was found that there was a large hyperbolic Elvis outflow structure about ten times further out.

The four components associated with these internal structures were found to be similar to the features revealed in simulated accretion flows into the central magnetic dipole objects contained within Young Stellar Objects, which have been successfully simulated by Romanova et al. Hence our main conclusion was that we were seeing a similar type of central magnetic object in this quasar and if so, such an object cannot be a black hole because black holes cannot possess an intrinsic anchored magnetic dipole field. Hence these observations were found to represent strong evidence for the existence of a new kind of central collapsed object in the quasar Q0957 called a "Magnetospheric Eternally Collapsing Object" (MECO) which is permitted within the framework of general relativistic gravity (SLR06).

MECO form by the same gravitational collapse process believed to result in black holes, but due to internal Eddington limited radiation pressure, they are never observed to collapse through an event horizon (Mitra, 2006). Due to the extreme surface redshift of a MECO, its surface radiation is too faint to be easily detected at astronomical distances. Hence MECO differ observationally from black holes primarily by the ability of the MECO to exhibit observable manifestations of its intrinsic magnetic field on its surrounding

accretion disk and environment.

While many models of quasars based on black holes exist in the literature, none of them are able to account all four of the components of the internal structure observed within Q0957. This was especially true for the observed inner accretion disk structure, which contained a large empty region that was truncated at a large radius by a very thin hot inner ring (illustrated white in Figure 7) characteristic of an intrinsic magnetic propeller interaction with the accretion disc. Hence we conclude in response to the question asked in the title of this report, that the observational evidence for the existence of a very hot thin luminous ring deep within quasar Q0957 represents a strong observational argument in favor of the existence of a supermassive MECO in the center of this quasar, instead of a black hole.

8. Acknowledgements

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9. Appendix I: Resolution of the Black Hole Information Paradox and the MECO Membrane Paradigm

Our main report was written specifically to show how direct observation, of a hot thin ring within the internal structure of the quasar Q0957, favors the existence of an intrinsically magnetic MECO object residing at the center of this quasar rather than a black hole. In this appendix we briefly discuss two additional properties of MECO which are more esoteric, but are nonetheless further capable of distinguishing them from Black Holes. The first property is associated with the manner in which the MECO resolves well-known the Black Hole Information Paradox, while the second is associated with what is known as the MECO Membrane Paradigm.

9.1. The MECO Resolution of the Black Hole Information Paradox

The Black Hole Information Paradox⁽¹⁾ results from the application of quantum field theory near the event horizon of a black hole which by necessity contains an internal singularity which can ultimately destroy all information about the physical objects which penetrate through the event horizon. Because of this, the black hole has the capability to perform non-unitary, information destroying measurement processes on the states of entangled quantum systems located outside of the black hole event horizon. This leads to the Black Hole Information paradox because this type of black hole information destroying measurement process violates the Principle of Unitarity associated with the conservation of probability in quantum field theory.

This type of quantum information paradox does not occur for the MECO. This is because its highly red shifted physical surface dynamically prevents the formation an event horizon containing internal information destroying singularities. Since there is no internal

information destroying singularity inside of the MECO, the surface of the MECO has the potential to perform an irreversible non-unitary measurement process, on the state of an entangled quantum system initially located outside of the event horizon, without violating the Principle of Unitarity associated with the conservation of probability in quantum field theory. In summary no quantum information paradox results for the MECO because: a) it satisfies the Strong Principle of Equivalence which implies that the inside and the outside of the MECO are capable of being connected by light signals, and; b) there are no singularities inside of the MECO surface which can destroy information.

9.2. The MECO Membrane Paradigm

The best way to understand the MECO Membrane Paradigm is by comparing it to the well-known Black Hole Membrane Paradigm (Price et al, (1988)). Since black holes have event horizons which are not physical surfaces, the Black Hole Membrane Paradigm is actually only an approximation used for visualizing and calculating the effects predicted by quantum field theory applied to the exterior physics of black holes. It models the black hole as having a thin classically-radiating surface vanishingly close to the black hole’s event horizon. In this picture the black hole is described by an array of exterior, stationary, non-inertial observers whose coordinate system ends at $r = 2R_g = 2GM/c^2$, since such observers cannot hover at or below the black hole event horizon under the rules of standard general relativity. These fiducial observers describe the “Hawking Radiation” (Hawking, (1975) produced by black holes as being emitted by an arbitrarily-thin shell of “hot” material at or just above the critical radius $r = 2R_g$ where this coordinate system fails. Hence while the physical effects of Hawking Radiation appear to be occurring all the way down to the event horizon of the black hole at $r = 2R_g$, they do not actually come from the event horizon because it is not a physical surface. However by associating this radiation

with a hypothetical thin radiating membrane located near the horizon, this allows models to be constructed which do not explicitly contradict general relativity's prediction that the boundary associated with the event horizon at $2R_g$ is inescapable.

In contradistinction to the case of black holes, MECO have highly red shifted physical surfaces which are not event horizons. Hence a MECO Membrane Paradigm can be constructed which is an exact result that can be used for calculating the effects predicted by quantum field theory exterior to the MECO surface. The highly red shifted Eddington limited radiating physical surface of the MECO is dynamically balanced by radiation pressure just outside of the radius $R = 2R_g$. In this context the MECO Membrane Paradigm states that this highly red shifted physical surface can be described by an array of exterior, stationary, non-inertial observers whose coordinate system can be continued up to and thru this physical surface of the MECO. This is allowed in the absence of an event horizon, since under the rules of standard general relativity such observers can dynamically hover at or below the physical surface of the MECO.

Since the red shift of the MECO surface has a large but finite value, Hawking Radiation plays no significant role in its dynamics. Instead the fiducial observers describe the source of the thermal radiation, produced by the highly red shifted MECO surface just outside of $R = 2R_g$, as being due to synchrotron radiation generated by a "hot" internal electron-positron plasma in the presence of the very strong intrinsic magnetic field of the MECO. Since there is no event horizon the physical effects of this surface radiation appear to be occurring all the way down as well, coming through the highly red shifted surface of the MECO.

Because of the very high red shift associated with the surface of the MECO, a distant fiducial observer would view the highly red shifted surface of MECO Membrane as containing information about the entire history of the MECO and its environment.

Hence the MECO Membrane Paradigm implies that the highly red shifted surfaces of the MECO have properties which allow them to act like cosmological memory storage devices within which the entire history of the Universe may be stored. This physical phenomenon associated with the MECO Membrane Paradigm may play a fundamental role in cosmological models of consciousness in the universe (Schild, 2010).

REFERENCES

- Antonucci, R. 1993. Unified Models for Active Galactic Nuclei and Quasars. *Annual Reviews of Astronomy and Astrophysics*, 31, 473-521.
- Colley, W. & Schild, R. 2000, “Hourly Variability in Q0957+561,” *ApJ*, 540, p. 104-112
- Colley, W. & Schild, R. 2003. A Rapid Microlensing Event in the Q0957+561A, B Gravitational Lens System. *ApJ*, 594, 97-100 (CS03).
- Colley, W. et al, 2003. Around-the-Clock Observations of the Q0957+561A,B Gravitationally Lensed Quasar. II. Results for the Second Observing Season. *ApJ*, 587, p 71-79.
- Hawking, S. 1997. Black Holes and the Information Paradox, *Scientific American*, April 1997 (cover story)
- Igumenshchev, I. Narayan, R. and Abramowicz, M. 2003. Three-dimensional Magneto-hydrodynamic Simulations of Radiatively Inefficient Accretion Flows. *ApJ*, 592, p 1042-1059.
- Igumenshchev, I. V. 2008, Magnetically Arrested Disks and the Origin of Poynting Jets: A Numerical Study. *ApJ* 677, p317-326.
- McKinney, J. & Narayan, R. 2007. Disc-jet coupling in black hole accretion systems - II. Force-free electrodynamic models. *MNRAS*, 375, p 513-547.
- Mitra, A., 2006. Sources of stellar energy, Einstein Eddington timescale of gravitational contraction and eternally collapsing objects. *New Astronomy*, 12, p146-160.
- Narayan, R. & Quataert, E. 2005. Black Hole Accretion. *Science*, 307, p 77-80.
- Oscz, A. et al, 2001, Time Delay in QSO 0957+561 from 1984-1999 Optical Data. *ApJ*, 552, p81-90.

- Price, R. and Thorne, K. 1988. The Membrane Paradigm for Black Holes. *Scientific American*, vol 258, No. 4(April 1988), p69-77.
- Refsdal, S. 1966. On the possibility of determining Hubble’s parameter and the masses of galaxies from the gravitational lens effect. *M.N.R.A.S.* 128, p307.
- Robertson, S. and Leiter, D. 2002. Evidence for Intrinsic Magnetic Moments in Black Hole Candidates. *ApJ*, 565, p447-454
- Robertson, S. and Leiter, D. 2003. On Intrinsic Magnetic Moments in Black Hole Candidates. *ApJ*, 596, L203-206.
- Robertson, S., and Leiter, D. 2004. On the origin of the universal radio-X-ray luminosity correlation in black hole candidates. *MNRAS*, 350, p1391-1396.
- Robertson, S., and Leiter, D. 2005, “ The Magnetospheric Eternally Collapsing (MECO) Model of Galactic Black Hole Candidates and Active galactic Nuclei. In “New Directions in Black Hole Research,” ed. P.V.Kreitler, Nova Science Publishers, Inc, ISBN 1-59454-460-3, novapublishers.com, p1-45.
- Romanova, M. et al, 2002. Magnetohydrodynamic Simulations of Disk-Magnetized Star Interactions in the Quiescent Regime: Funnel Flows and Angular Momentum Transport. *ApJ*, 578, p420-438.
- Romanova, M. et al, 2003a. Magnetohydrodynamic Simulations of Accretion onto a Star in the “Propeller” Regime. *ApJ*, 588, p400-407.
- Romanova, M. et al, 2003b. Three-dimensional Simulations of Disk Accretion to an Inclined Dipole. I. Magnetospheric Flows at Different Theta. *ApJ*, 595, 1009-1031.
- Romanova, M. et al, 2004. The Propeller Regime of Disk Accretion to a Rapidly Rotating Magnetized Star. *ApJ*, 616, L151-155.

- Schild, R., 1990. The time delay in the twin QSO Q0957 + 561. *AJ*, 100, p1771-1776.
- Schild, R. E. 1996. Microlensing Variability of the Gravitationally Lensed Quasar Q0957+561 A,B. *ApJ*, 464, p125-130.
- Schild, R. E. 1999. A Wavelet Exploration of the Q0957+561A,B Brightness Record. *ApJ*, 514, p 598-606.
- Schild, R. E. 2004a. Some Consequences of the Baryonic Dark Matter Population. astro-ph/0409549.
- Schild, R. E. 2004b. The Detection and Nature of the Baryonic Dark Matter. astro-ph/0406491.
- Schild, R. E. 2005. Accretion Disk Structure and Orientation in the Lensed and Microlensed Q0957+561 Quasar. *AJ*, 129, p1225-1230.
- Schild, R. E. 2007, The Evolution of the Chemical Elements of the Universe. astro-ph/07082917.
- Schild, R. E. 2010. A Computer Model of Consciousness. in *Anthropology of Consciousness*, in preparation
- Schild, R. E., & Cholfin, B. 1986. CCD camera brightness monitoring of Q0957 + 561 A, B. *ApJ*, 300, p 209-215.
- Schild, R. E., & Thomson, D.J. 1995. Twin QSO Q0957+561 Time Delay Dataset. *AJ*, 109, p1970.
- Schild, R. E. & Thomson, D.J. 1997. The Q0957+561 Time Delay From Optical Data. *AJ*, 113, p130.

- Schild, R. E. & Vakulik, V. 2003. Microlensing of a Ring Model for Quasar Structure. *AJ*, 126, p 689-695.
- Schild, R. E. & Dekker, M. 2007. The Transparency of the Universe limited by Ly-alpha Clouds. *A.N.* 327, p729.
- Schild, R. Leiter, D. & Robertson, S. 2006. Observations Supporting the Existence of an Intrinsic Magnetic Moment inside the Central Compact Object within the Quasar Q0957+561. *AJ*, 132, p420-432 (SLR06).
- Schild, R. Leiter, D. & Robertson, S. 2007. Direct Microlensing-Reverberation Observations of the Intrinsic Magnetic Structure of Active Galactic Nuclei in Different Spectral States: A Tale of Two Quasars. *AJ*, 135, p 947-956.
- Schmidt, M. 1965, Optical Spectra and Redshifts of 31 Radio Galaxies. *ApJ*, 141, 1.
- Shakura, N. & Sunyaev, R. 1973. Black holes in binary systems: Observational appearance. *A&A*, 24, p 337-355.
- Suskind, L. 1997, Black Holes and the Information Paradox, *Scientific American*, April 1997 (cover story).
- Susskind, L. (2008), *The Black Hole War: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics*, Little, Brown, ISBN 0-316-01640-3.
- Thomson, D. J. & Schild, R. 1997, in *Applications of Time Series Analysis in Astronomy and Meteorology*, ed. T. Subba Rao, M. Priestly, & O. Lessi [Chapman and Hall: New York], p187.
- Vakulik, V. et al, 2006. Observational determination of the time delays in gravitational lens system Q2237+0305. *A&A*, 447, p905-913.

Vakulik, V. et al, 2007. Q2237+0305 source structure and dimensions from light-curve simulation. MNRAS, 382, p819-832.

Walsh, D. Carswell, R. and Weymann, R. 1979. 0957 + 561 A,B - Twin quasistellar objects or gravitational lens. Nature, 279, p381-384.

Wozniak, H. et al, 2000. The Optical Gravitational Lensing Experiment Monitoring of QSO 2237+0305. ApJ, 529, p88-92.

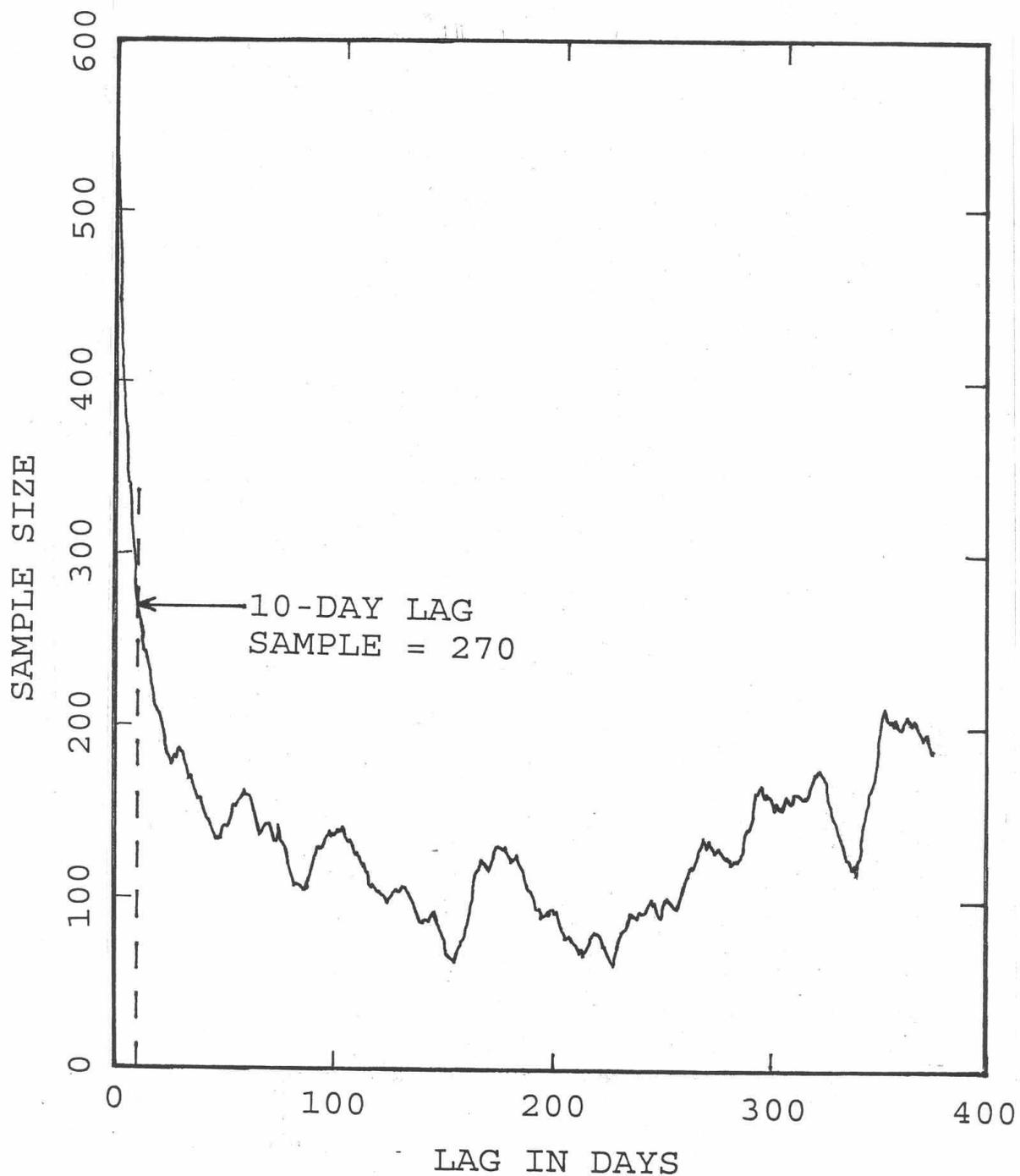


Fig. 1.— The data sample size emphasizing the number of nights contributing to correlation estimates of quasar brightness. As described in the text, interpolations of up to 2 days were included to describe the quantity of data contributing to correlation calculations. For the present example, data measured first in image A and compared to the later arriving B image, measure in the hundreds, for lags relevant to quasar structure, as well as to microlensing.

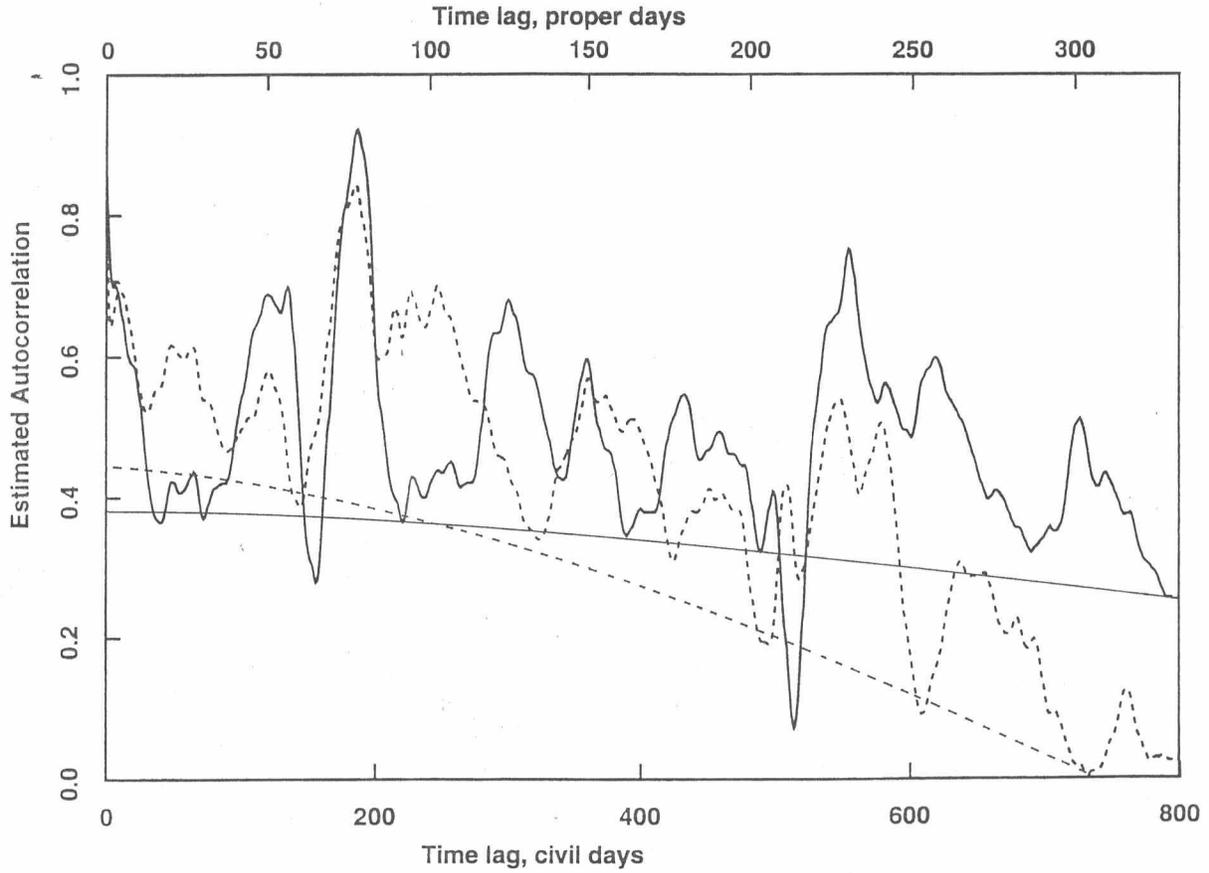


Fig. 2.— An autocorrelation plot for the A (dashed curve) and B(solid curve) quasar images. While previously this data analysis was used to infer the quasar outer structure, we now emphasize the evidence for inner structure, for lags less than 20 days (civil days). The central peak, near 0 lag, does not have the rapid falloff with a time scale near the sampling time expected for noise-dominated data. Instead it shows structure on time scales near 20 days, understood as indicative of inner quasar structure.

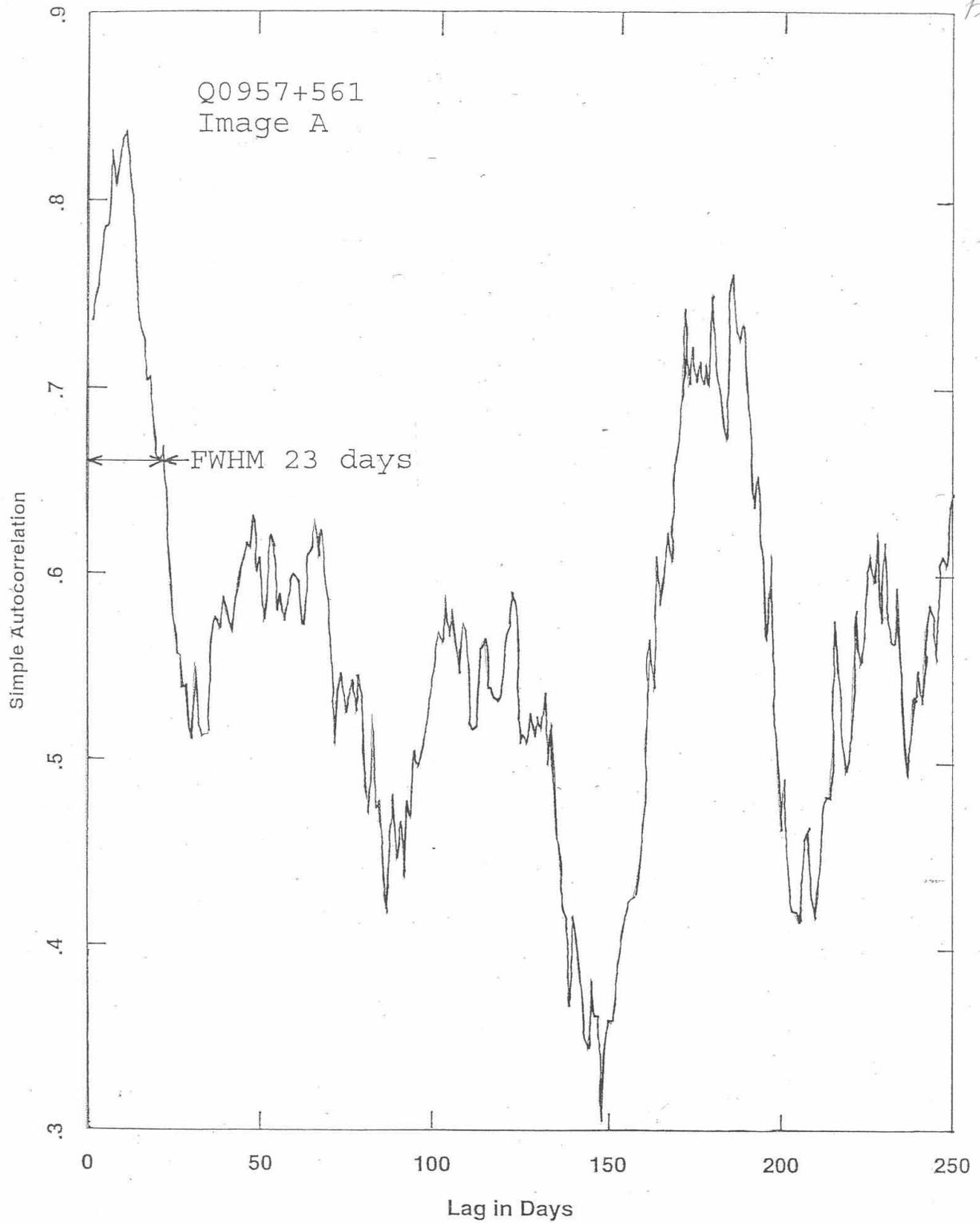


Fig. 3.— An autocorrelation plot of the image A data with finer resolution for smaller lags. Prominently seen are the lags for outer Elvis structures, as well as structure from the central peak with an overall half-width of 23 days and finer sub-structure at 6, 11, and 20 days.

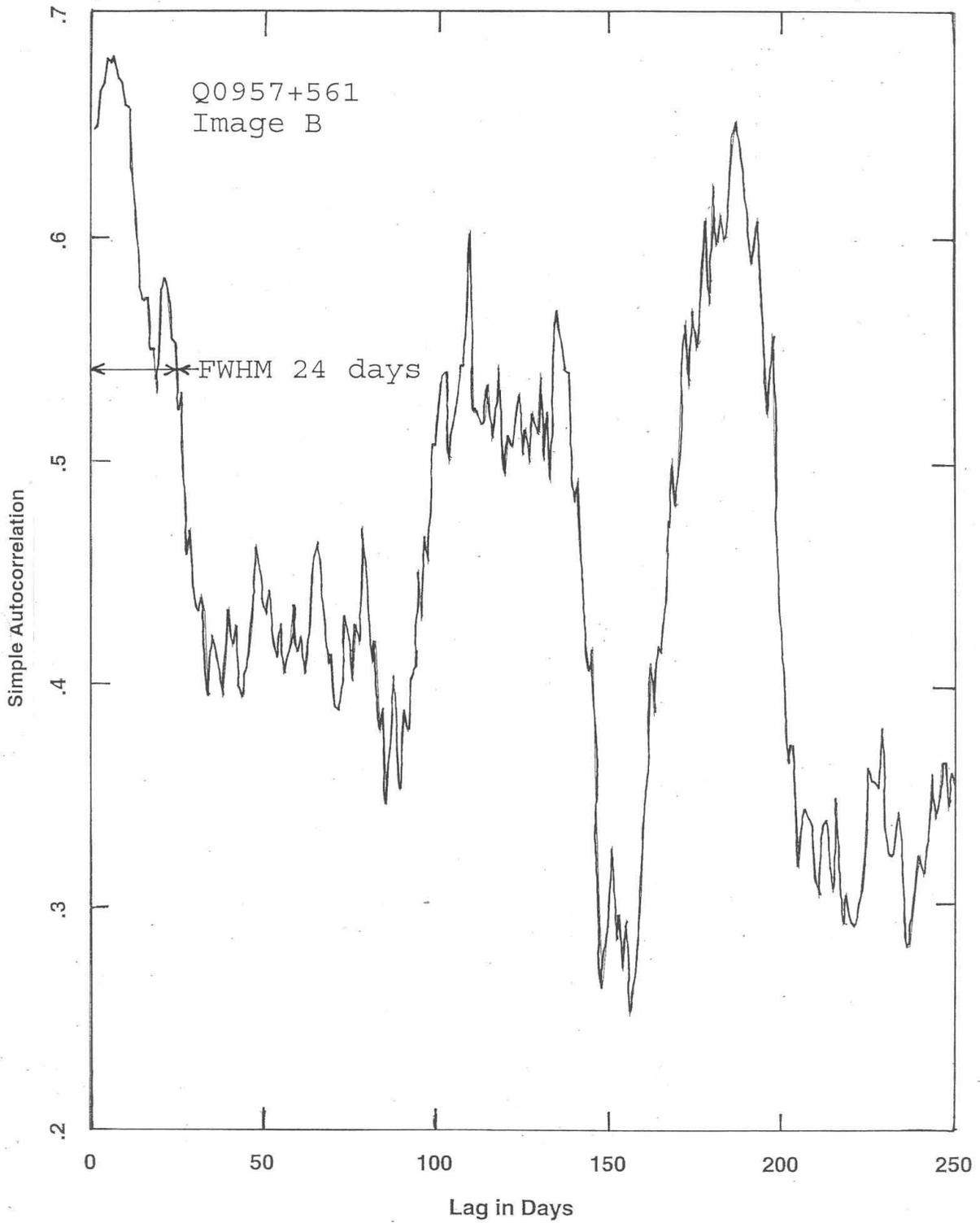


Fig. 4.— A fine structure autocorrelation plot for the B quasar image. Strong autocorrelation peaks at 129 and 192 days from the outer Elvis structures are evident. Also well seen is the structure surrounding the central peak and evidencing central quasar structure. The overall width is approximately 24 days, and substructure peaks are found at 5 and 20 days.

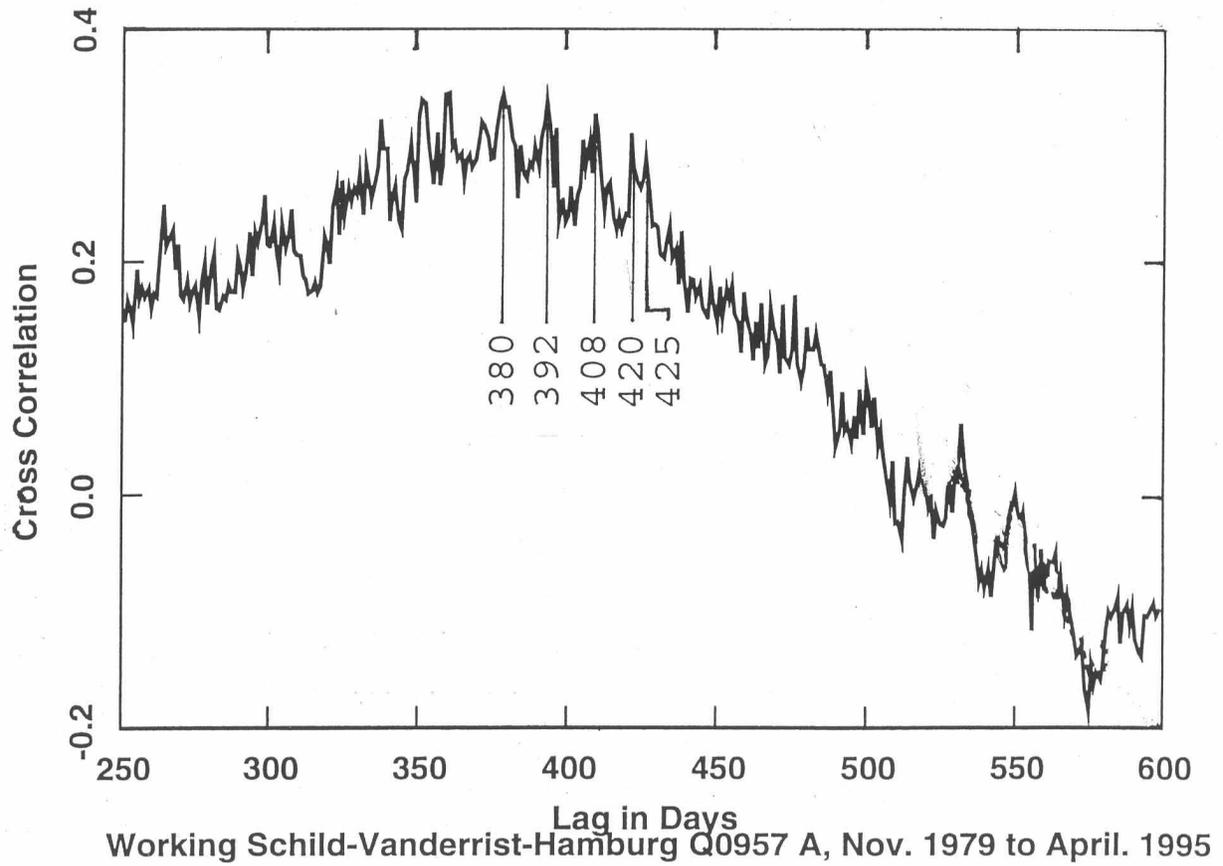


Fig. 5.— A cross-correlation plot centered on the value of the cosmological time delay, but showing the complications from quasar structure. In a simplistic view with no influence of quasar structure, the cross-correlation should be a strong peak at the cosmological value, 417 days. Because of quasar structure, a broad peak with FWHM near 100 days is found instead. Fine structure within this broad peak is evidently indicative of the quasar's inner structure.

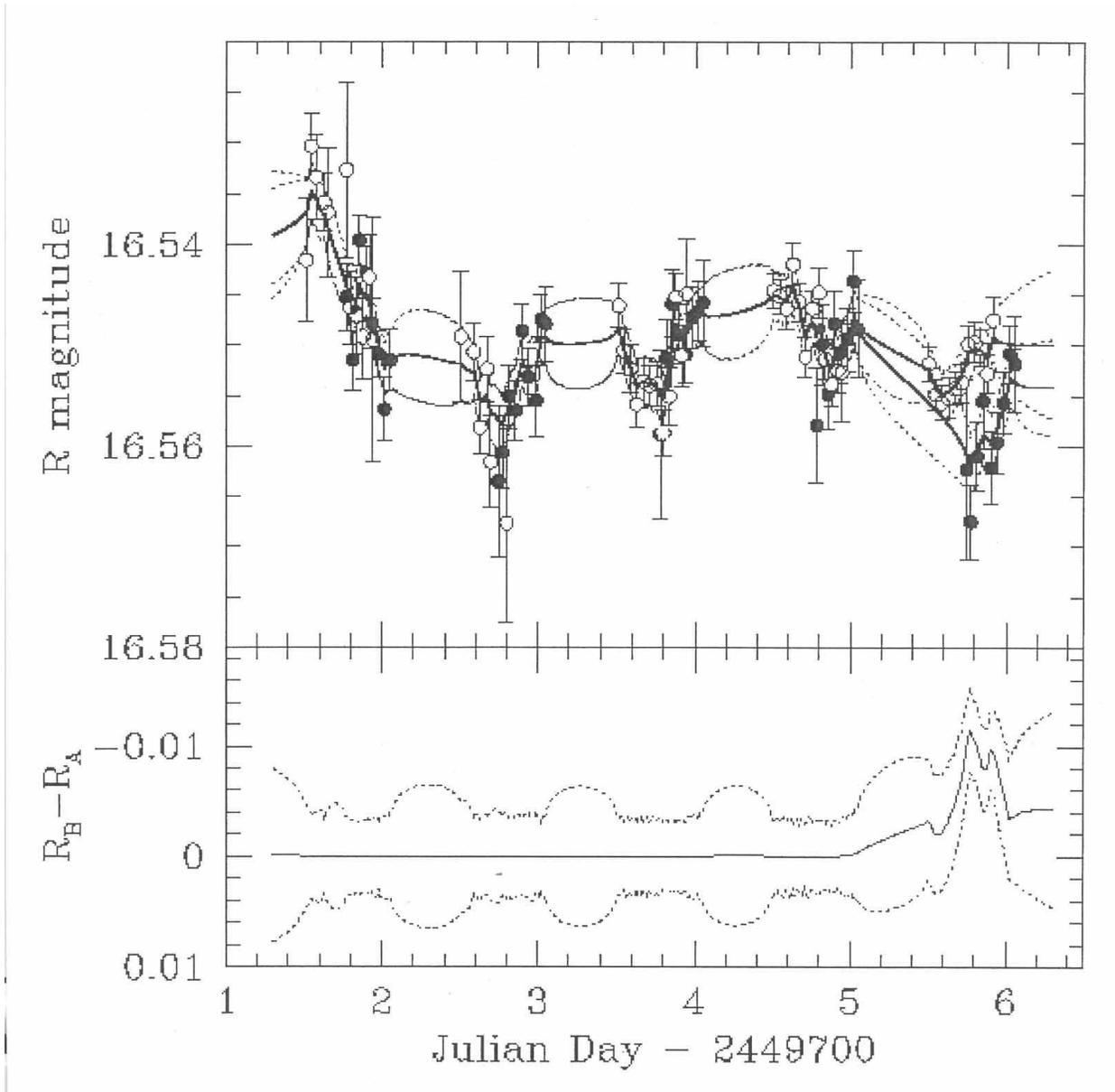


Fig. 6.— A simple plot of R magnitude measured for image A (open circles) in 1995.9 and in 1997.1 for image B (filled circles). A pattern of well-defined quasar brightness variations seems indicated for the first four nights. But on the fifth night, the brightness records significantly diverge, meaning that microlensing by a planet mass compact object in the microlensing galaxy made image B fainter on a time scale of hours. In the lower panel, the smoothed time-delay-corrected A-B magnitude is plotted with linear interpolation, and with 1σ outer limits per hourly data point shown as a dotted line. We see that the rapid microlensing event at JD 2449706 was securely observed as probably an event where the quasar faded and the microlensing also diminished.

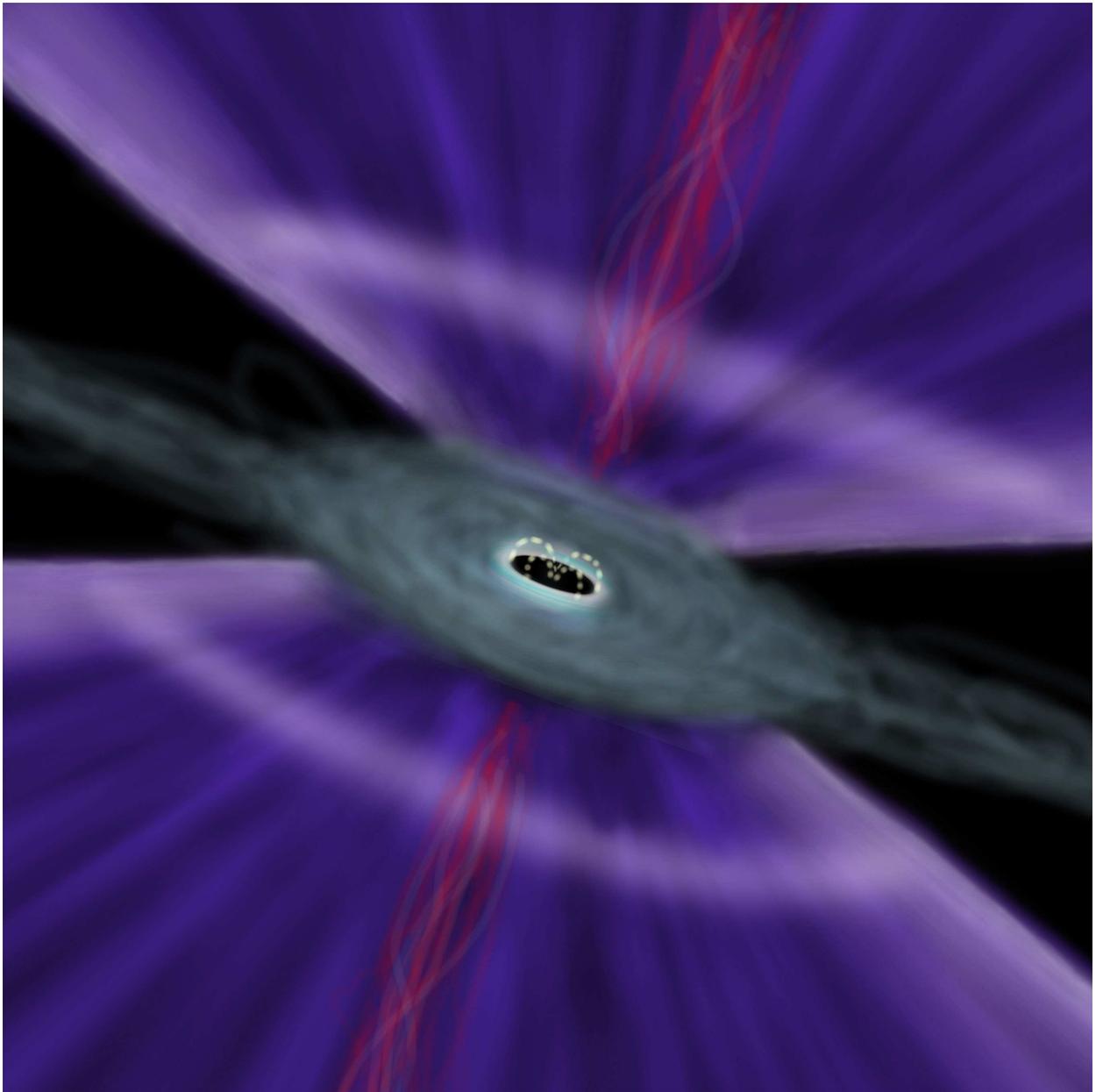


Fig. 7.— A schematic figure demonstrating the principal luminous quasar structures as determined by our reverberation-microlensing analysis. The dark compact central object is surrounded by dipole field lines (dotted yellow) and the sharp luminous ring at the inner edge of the accretion disc is white. A dark accretion disc intersects the outflow wind structures (Elvis surfaces) whose fluorescence above and below the plane (blue) contributes to the UV-optical continuum observed. The compact radio core (red) is shown in size and distance scaled to the overall structure.